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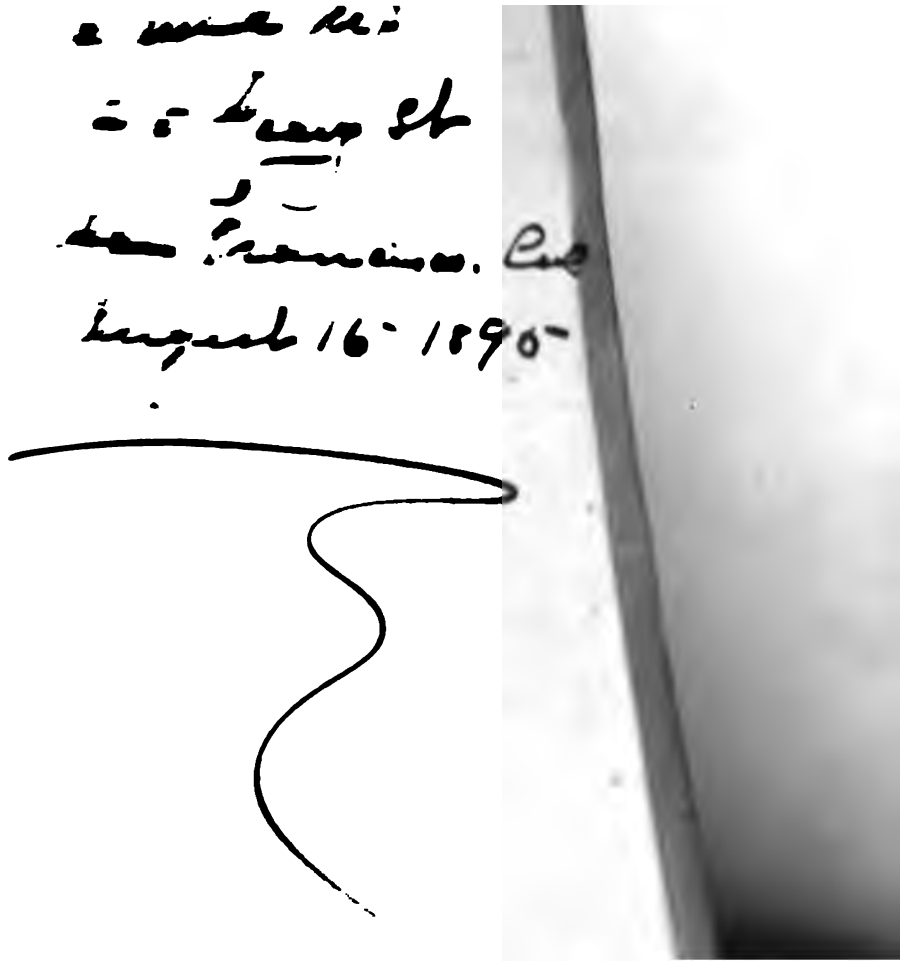

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SYSTEM

OF

SURGERY.

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VOL. I.

THE HISTORY OF SURGERY—PATHOLOGY—BACTERIOLOGY—INFECTIONS—ANÆSTHESIA—FRACTURES AND DISLOCATIONS—OPERATIVE SURGERY.

PROFUSELY ILLUSTRATED.

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PREFACE.

THIS *System of Surgery* is intended to meet a growing want created by the great progress which Surgery has made during the past few years. It is with a view to fulfil this object that men of recognized authority in their respective branches have consented to contribute in order to present to the profession a complete review of the domain of modern Surgery—a domain which has so wonderfully enlarged its boundaries through the achievements rendered possible by the systematic employment of antiseptic and aseptic methods of procedure. The task has been most onerous, but the labors of an eminent corps of contributors have enabled the Editor to offer to the profession a concise and complete work, presenting the most advanced opinions upon the new problems involved in modern surgery, as well as the practical details which conduce to success in treatment. In accomplishing this it is gratifying to be able to announce that the whole has been the work of American surgeons, and that it may be fairly said to represent the most advanced condition of American Surgery.

The Editor takes this occasion to acknowledge his obligations to the contributors, each one of whom is a teacher of Surgery or a director in some large surgical clinic or hospital, and who, for this reason, is capable of speaking with clinical authority from an experience based on the study and observation of a large number of cases. Each department is thus treated by an acknowledged master of the subject, who is able to present the most modern and advanced views in the most cogent and demonstrative way.

The Editor trusts that he will be found to have succeeded in the endeavor to present a work of the scope and breadth that this great subject demands, and that an appreciative reception will be accorded to the results given by the contributors, who, though busy men, have consented to offer the fruits of their labors for the benefit of the medical profession.

The Editor especially desires to acknowledge, with sincere thanks, the great assistance accorded to him by DR. JOHN S. BILLINGS, through whose valuable services and co-operation he has been enabled to bring before the profession this work in its present comprehensive and at the same time compact form.

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THE HISTORY AND LITERATURE OF SURGERY.

By JOHN S. BILLINGS, M. D.

In this sketch of the development of Surgery during the last three thousand years a brief account is given, mainly in chronological order, of the chief discoverers, improvers, and inventors in the art, and also of the principal teachers of it. The original inventor may or may not have been a lecturer or author, and the date of the first improvement in a method of treatment or in the performance of a new operation was often long prior to that general knowledge of such improvement which is necessary to constitute true development. Some account is also given of the trade, guild, or craft associations or corporations of surgeons, and of their relations to education and to legislation. A few illustrations of the state of the art at different periods, in the shape of the recommendations of different writers with regard to methods of treatment of certain injuries or diseases, are presented; but no attempt is made to trace the history of the growth of knowledge with regard to each particular form of disease or operation, this being left to the writers of monographs on these particular subjects.

It requires leisure, patience, and access to a large library to make historical studies really interesting, and the most I can hope to accomplish in this paper is to furnish to the physician who has little time, taste, or opportunity for consulting the original documents the means of ascertaining the periods and places in which the leading surgeons of the world have done their work. The printed literature of surgery is vast in quantity, and the great majority of it is obsolete and practically useless: even for statistical purposes the records of operations performed prior to 1870 have now lost much of the value which they possessed at that date; yet in many respects the old surgical monographs, collections of cases, and systems are the most definite and interesting of all ancient medical literature.

To really enjoy the history of surgery it is necessary to consult the original documents—to get the flavor of the quaint phraseology of the older writers. No discourse about the surgical knowledge of Hippocrates, however eloquent and eulogistic it may be, can give such an idea of his teachings as is to be obtained from a perusal of his writings.

It is not to be expected that a man who is familiar with the resources of the surgery of the present day will be able to discover in the ancient records anything of much practical utility in his daily work which will be new to him; nevertheless, if he desires to compare his experience in a particular case or class of cases with that of his predecessors—to obtain,

as it were, a sort of "parallax in time" of the views which have been held on the subject which occupies him—he will often not be able to do this from the current text-books. It will be necessary that he should go back to the old masters, read, compare, and think; and whenever he does this it is safe to say that his conclusions will be broader, wiser, established on a firmer foundation, and more interesting to those to whom he imparts them, than they will be if derived solely from his own experience.

In the history of the development in civilization of nations and peoples, surgery almost necessarily precedes internal medicine with regard to accurate observation of lesions of the human body and of their results. Speculations about humors and fluxes, black bile and medical constitutions, vital spirits and the doctrine of signatures, did not much occupy the minds of the men of old in their attempts to note and describe the signs of different forms of fractures and dislocations, the danger of wounds in different localities, the different varieties of tumors, or the treatment of a calculus in the bladder or of a hernia. Of the many remedies in the form of drugs, salves, embrocations, and plasters which are described at length in the ancient medical books which have come down to us, hardly more than twenty are now in ordinary use; the ancient physiology and pathology are, for the most part, now considered as being merely curious illustrations of human error; and it is only a portion of the anatomy and surgery of the ancients that remains as an essential part of the foundation of the art of medicine as it exists to-day.

The history of surgery is inextricably mingled with that of medicine, and the best literature on the subject is to be found in some of the larger formal treatises on the history of medicine. It has, however, been treated of as a special branch of the art in a goodly number of books and essays, the titles of a portion of which fill seven pages of volume xiii. of the Index Catalogue of the Library of the Surgeon-General's Office at Washington.

The earliest records in our possession which relate to surgical operations come from Egypt. It is true that human skulls have been found belonging to the Neolithic or Polished Stone Age, which have had portions removed—being examples of the so-called prehistoric trephining which is supposed to have been performed in cases of headache, epilepsy, etc.—and the age of these relics is unknown; but it is not at all probable that it extends to the time of the pyramid-builders in the valley of the Nile, when circumcision had been established as a religious rite and an official system of medicine was in process of construction.

The Papyrus Ebers, written 1552 B. C.—that is, at least a century before the exodus of the Israelites—is a compilation of receipts and directions for the treatment of various diseases, many of which formulæ it refers to as being then ancient. Among these is a short section on tumors near the surface of the body, in which it is said: "If this tumor goes and comes under your finger, trembling even when your hand is still, say, 'it is a fatty tumor,' and treat it with the knife, after which treat it as an open wound." From the Papyrus Ebers we learn that there were physicians in Egypt who were not priests, and the same may be inferred from the statement in Genesis (ch. l. 2) that "Joseph commanded his servants the physicians to embalm his father, and the phy-

sicians embalmed Israel." The word in this text which is translated "physicians" is *rephaim*, and it is sometimes translated as "dressers of wounds"—*i. e.* surgeons. The embalmers probably had a little more anatomical knowledge than the physicians of the time; but the Egyptians had a treatise on anatomy which, according to Manetho, was attributed to Athothis, the son of Menes, who reigned 5241 B. C.

The few allusions to medicine scattered through the books of the Old Testament indicate that the general belief was in accord with that usually found prevailing among savage tribes—viz. that most diseases are punishments inflicted by divine power, and to be removed by sacrifices and special ceremonies; whence it follows that the priests were the chief medicine-men. That there were other physicians is probable from the grimly sarcastic account of King Asa, who "in his disease sought not to the Lord, but to the physicians. And Asa slept with his fathers;" and also, perhaps, from Exodus xxi. 19: "And if men strive together, and one smite another with a stone, or with his fist, and he die not, ... then shall he that smote him pay for the loss of his time, and shall cause him to be thoroughly healed;" or, as the Septuagint has it, "and shall pay the physician's fees."

The medicine of the Bible has been the subject of several learned essays, but it does not appear that medicine was regularly studied among the Jews as a separate profession until the rise of the Alexandrian School, nor does either the science or the art of medicine owe anything to this nation until after this period. The often-quoted chapter xxxviii. of Ecclesiasticus about the physician is of late date, and was probably written under Greek influence.

Some specimens of Jewish surgery prior to 200 A. D. are to be found in the Talmud. The rabbis were acquainted with sutures for wounds, with the method of freshening the edges of an old wound to obtain reunion, with the employment of the uterine sound to learn whether the blood came from the uterus or vagina, the operation for imperforate anus, and also with anæsthetic substances with which they used to diminish the pain of a surgical operation or capital punishment.[1] They understood the application to the body of artificial parts, as for supplying the loss of substance of the trachea and replacing the loss of substance of the cranial bone; they knew artificial teeth, wooden legs, as also various forms of apparatus for the unfortunates who were deprived of the use of their lower extremities.

The first allusions to surgical subjects in Greek literature are found in the poems of Homer, which may be accepted as dating from about 1000 B. C., whatever may be thought as to the reality of the siege of Troy or the identity of Homer himself. In these poems mention is made of Æsculapius, not as a god, but as a well-known and distinguished physician, and of his sons Machaon and Podalirius as surgeons and warriors. The works of Homer have been carefully examined and analyzed by Malgaigne and Daremberg with reference to medical and surgical matters, and their conclusions may be briefly stated as follows:[2]

[1] Rabbinowicz: *La Médecine du Thalmud, etc.*, Paris, 1880, p. xliii.

[2] "Essai sur l'Histoire et l'Organisation de la Chirurgie et de la Médecine grecques avant Hippocrate," par M. Malgaigne, *Jour. de Méd.*, iv. 303, Paris, 1846; *La Médecine dans Homère*, par Ch. Daremberg, 8°, Paris, 1865.

Among the Greeks were certain surgeons whose knowledge and skill were highly esteemed; many of the warriors knew how to dress and bandage wounds, and some of the Grecian women had the same skill, corresponding to that possessed by the wives of the nobility in Western Europe in feudal times. The dressings applied to the wounds appear to have been for the most part simple emollients: the effused blood was pressed out, the surface was washed with warm water, certain crushed roots or bruised leaves were applied to check hemorrhage. Over forty wounds in different parts of the body are described with more or less detail, and in such a way as to indicate that Homer gave the results of actual observation and experience; and in the course of these descriptions a nomenclature is used which, anatomically, is much the same as that employed by Hippocrates. The different effects of wounds in different parts of the body are referred to, and a curious illustration of this occurs in the description of the injury of one of the horses of Nestor by an arrow from the bow of Paris (viii. 81–86). The wound was on the top of the head, penetrating to the brain, and it is said that the injured animal was convulsed and turned round and round the pole. This, as Malgaigne points out, corresponds to the modern discovery that such movements of rotation are produced by an injury of the cerebellum.

The anatomical terms used by Homer relate mainly to the exterior of the body, and do not imply any greater knowledge of internal structure than is possessed by every butcher; but his allusions to the fatality of certain wounds embody the results of considerable experience. There is nothing of surgical interest in Greek literature between the time of Homer and that of the Hippocratic Writings, unless it be the passage in Aristophanes in which the slave of Lamachus calls for hot-water compresses, etc. with which to dress the sprained ankle of his master.

In the fifth and sixth centuries B. C. there were in Greece and Great Greece between fifty and sixty temples of Æsculapius, all of which were probably resorted to by the sick, but those which became specially celebrated were those of Rhodes, Cyrene, Cnidos, and Cos. Those at Cnidos and Cos gradually became the most famous, and their so-called "schools" occupy a prominent place in the history of medicine.

By the term "medical schools" as applied to Cos and Cnidos it is not meant that these were places for the public teaching of medicine, but rather that they were places where certain medical families had settled, and in each of which certain peculiar theories and methods of treatment prevailed, the phrase "school" being used much as we would now speak of the "French" or the "Munich" school in painting.

In the vicinity of these temples there seem to have collected physicians who were not priests, and who belonged to an association or brotherhood, the members of which either claimed to be descendants of Æsculapius or were admitted to the guild by adoption with special ceremonies. These were known collectively as the "Æsclepiadæ," and much confusion has arisen from the erroneous application of this term in later times to those who ministered in the temple. There is no doubt that the priests of the temple gave medical advice, but, if we are to judge from the specimens preserved to us in the forms of inscriptions and memorial tablets, it was not the sort of advice of which any use is made in the medical treatises of the Hippocratic school.

It is probable that the real or lay physicians kept records which were handed down from father to son, and were preserved as a valuable family heritage. That medicine was thus hereditary we know from the Hippocratic oath, and from the genealogies which are given of many of the celebrated physicians of Greece. According to Bertrand, this custom has come down to the present time. On one of the slopes of Pindus there are still five or six villages the inhabitants of which are supposed to be born physicians and surgeons, each family having its own specialty and its inherited tradition. If a son is wanting, the child of a stranger is adopted.

There is no evidence that those who visited the temples seeking miraculous cures were examined or treated by lay physicians, but there were certain attendants called *zacoroi* who received the patients and assigned them to places beneath the porticos; and from the information collected by them it is possible that the priest who impersonated the god, appearing in the night-watches, may sometimes have formulated his prophecies and instructions.

The doctrines of the schools of Cos and Cnidos were committed to writing, the first work of the kind coming from the school of Cnidos, being what is known as the "Cnidian Sentences." Of this treatise there were at least two editions, and it was in existence in the time of Galen. A portion of it has been preserved to us in what are known as the Second and Third Books of Diseases, and in the Treatises on Internal Affections contained in the Hippocratic collections.

In this portion four diseases of the kidneys are described. In the first there is acute pain in the loins, groin, and the testicle of the affected side (renal colic); there is frequent urination, with gradual suppression of urine and passage of sand, causing pain in the urethra. Apply warmth and purge with scammony. If the pain is great, use large enemata of warm water; if a tumor forms, make an incision over the kidney and evacuate the pus. Such incision gives a chance of recovery; without it death will follow.

In the second form of disease of the kidney there are violent pains, as in the preceding form. The patient passes blood with his urine at the commencement of the disease, which is followed, after a time, by pus. If he preserves a strict rest, he will be cured rapidly, but if he makes effort, the pains will become sharper. When the kidney is filled with pus it swells out near the spine; in this case make, over the swelling, an incision, generally deep, into the kidney. If you succeed in the incision, you will cure the patient at once; if you fail, it is to be feared that the wound will not close, and the borders of the wound will contract and the cavity of the kidney will be filled with pus; if this passes inward and is evacuated by the rectum, there is a chance of health; but if it affects the other kidney, death is to be feared. Evacuants are to be used, and the same regimen as for the preceding case. Very often this disease terminates by a renal phthisis.

The school of Cos followed with its collection of maxims, the "Prænotiones Coacæ." Its doctrines will be best considered in the work of its most illustrious disciple, Hippocrates, who was born at Cos about 460 B. C. His father, Heraclides, and his grandfather were physicians, and he received his early education at the school of Cos, after which he went

to Athens and continued his studies, receiving the best education which the Golden Age of Greek civilization could furnish.

The collection known as the "Hippocratic Writings" dates from a period about the time of Aristotle. Only a portion of these writings are the works of Hippocrates himself; several are probably of more ancient date—two at least appear to belong to the Cnidian School, and some are by his disciples. On the other hand, some of those which once belonged to this collection have been lost.

The books in the Hippocratic collection which treat more especially of surgical affections and operations, and which are accepted by most commentators as having been written either by Hippocrates himself or by one of his immediate pupils, are those on injuries of the head, on fractures, on the articulations (*i. e.* on dislocations), Mochlicus (on the bones and their injuries and displacements, and on apparatus), on wounds and ulcers, on fistulæ, on hemorrhoids, and on the Iatrium or the Physician's Establishment, or the Surgery.

The book on injuries of the head begins with a description of the sutures of the cranium and of the bones of the skull, in which it is stated that the number and position of the sutures varies with the form of the head; that the coronal suture is wanting when there is no anterior protuberance of the skull, and the lambdoid suture is wanting when there is no posterior protuberance. As this does not agree with the observations of modern anatomists, the commentators have much trouble to explain it, since they are unwilling to admit that Hippocrates made a mistake in observation, or even that he generalized from insufficient data; which last is the most probable explanation.

He divides injuries of the bones of the skull into five classes—viz. simple fissures, contusions without fracture or depression, fractures with depression, indentations of the outer table, and fractures at a distance from the place of injury, or fracture by contre-coup. With regard to this last he says: "There is no remedy, for when this mischief takes place there is no means of ascertaining by any examination whether or not it has occurred, or on what part of the head." He then goes on to say: "Of these modes of fracture the following require trepanning: the contusion, whether the bone be laid bare or not; and the fissure, whether apparent or not. . . . . A bone depressed from its natural position rarely requires trepanning, and those which are most pressed and broken require trepanning the least."

It will be seen that this is quite different from the rules of modern practice.

For wounds of the head he forbids the application of any liquors or cataplasms or tents, unless the wound is on the forehead or the part which is bare of hairs or about the eyebrow and eye. The wound is to be extended by incisions for the purpose of examining the bone whenever it is suspected that this is injured; and it is remarked that these incisions may be practised with impunity except on the temple and the parts above it, where there is a vein that runs across the temple, in which region an incision is not to be made; "for convulsions seize on a person who has been thus treated; and if the incision be on the left temple, the convulsions seize on the right side; and if the incision be on the right side, the convulsions take place on the left side."

The books on fractures and on the articulations, together with the book called "Mochlicus," contain sketches of the anatomy of the bones and of the joints, and accounts of various forms of dislocations of the different joints, with detailed instructions as to reduction and as to the mode of bandaging in cases of fracture. Special attention is given to the subject of injuries affecting the knee-, the elbow-, and the ankle-joints.

The paragraph on dislocations of the knee does not correspond to the experience of modern surgeons. It is as follows: "Luxations and subluxations at the knee are much milder accidents than subluxations and luxations at the elbow; for the knee-joint, in proportion to its size, is more compact than that of the arm, and has a more even conformation, and is rounded, while the joint of the arm is large and has many cavities. . . . .

"Owing to their configuration, the bones of the knee are indeed frequently dislocated, but they are easily reduced, for no great inflammation follows nor any constriction of the joint. . . . . They are displaced for the most part to the inside, sometimes to the outside, and occasionally into the ham. The reduction in all these cases is not difficult, but in the dislocations inward and outward the patient should be placed on a low seat, and the thigh should be elevated, but not much. Moderate extension for the most part sufficeth, extension being made at the leg and counter-extension at the thigh.

"Dislocations at the elbow are more troublesome than those at the knee, and, owing to the inflammation which comes on and the configuration of the joint, are more difficult to reduce if the bones are not immediately replaced. For the bones at the elbow are less subject to dislocation than those of the knee, but are more difficult to reduce and keep in their position, and are more apt to become inflamed and ankylosed."

Some of the older surgeons concur with Hippocrates in speaking of dislocations of the knee as comparatively frequent, whereas at present they are very rare. Dr. Adams supposes that the wrestlers at the public games, who furnished Hippocrates with a large proportion of his cases of fractures and dislocations, may have been especially liable to this accident. Hippocrates says that he knows of but one way in which the shoulder-joint is dislocated—namely, that into the armpit; but he does not deny that the head of the humerus might be dislocated upward, outward, or forward. The methods of reduction are fairly described, and are substantially those which are used at the present day.

He has much to say in various places about congenital dislocations, some of which may be reduced to their natural condition, and especially those at the ankle-joint.

In cases of compound dislocations he forbids reduction, as a general rule. For example, in speaking of dislocation at the ankle-joint complicated with an external wound, he says you are not to reduce the parts, but let any other physician reduce them if he choose; "for this you should know for certain, that the patient will die if the parts are allowed to remain reduced, and that he will not survive more than a few days, for few of them pass the seventh day, being cut off by convulsions; but sometimes the leg and foot are seized with gangrene. . . . . But if not reduced nor any attempts first made to reduce them, most of such cases

recover. The leg and foot are to be arranged as the patient wishes, only they must not be put in a dependent position nor moved about."

In speaking of these compound dislocations he makes no allusion to cutting off the protruding end of the bone, but in another section he remarks that "complete resections of bones at the joints, whether the foot, the hand, the leg, the ankle, the forearm, the wrist, for the most part are not attended with danger, unless one be cut off at once by deliquium animi or if continual fevers supervene on the fourth day."

Hippocrates knew nothing about amputation of limbs as an operation through living parts or with a view to forming a stump of a particular shape. In cases of gangrene due to the crushing of the blood-vessels, or following fractures when the bandages have been applied too tightly, he remarks that the most of such patients recover, even when a portion of the thigh comes away or of the arm, and when the forearm and leg drop off the patients rapidly recover.

The surgical part of the Hippocratic collection is much more in accordance with modern views than the medical part; but there are certain characteristics of all the books generally considered to have been written by Hippocrates himself which are worthy of special attention in connection with the high repute in which they have been held by medical men for over two thousand years. In the first place, it is evident that one of his special aims was to be entirely honest and truthful in his statements. He reports no marvellous cures, no specimens of extraordinary success in diagnosis where others had failed; fatal cases are given as well as recoveries, and there are no hints that the former were not seen in time or that they had been improperly treated by others. He seems to have written mainly for the purpose of telling what he himself knew; and this motive—rare among all writers—is especially rare among writers on medicine.

A second characteristic of the Hippocratic Writings is the special attention given to those symptoms which indicate the effect which the disease is producing upon the body as a whole, including such phenomena as fever, debility, delirium, restlessness, and so-called critical discharges of various kinds; while the special diagnostic signs of particular forms of disease of particular organs are given much less attention.

The aphorism of Hippocrates concerning the efficiency of fire—namely, "that diseases which are not cured by medicines are cured by iron; those which are not cured by iron are cured by fire; those not cured by fire are incurable"—has been the cause of an enormous amount of suffering and of bad surgery to nearly the present century.

Surgery of India and China.

In the literature of India the first definite hymns, invocations, and charms connected with medicine are found in the fourth (or Atharva) Veda. The oldest existing medical work is the Charaka-samhita, of which the Sanscrit text has been published in 1877, and of which an English translation is now in course of publication. Somewhat later, probably, is the Susruta, of which two Sanscrit editions have been published; also a Latin translation by Dr. F. Hessler, published at Erlangen in 1844. English translations are in progress of publication, and a sum-

mary is given by Dr. Wise in his history of Indian medicine. Both Charaka and Susruta profess to be, and are commonly said to be, commentaries on the Ayur-Veda—*i. e.* the Veda of Life—but, in fact, there is no such work as the Ayur-Veda distinct from and preceding Charaka and Susruta.

The date of composition of these works is unknown, and is variously estimated at from 1000 B. C. to 700 A. D. Recent authorities consider that the later date is the more probable one, and that the work took its present form under the influence of ideas derived from the Alexandrian School and the early Arab writers. It was certainly known in the ninth century A. D. Nevertheless, it shows little trace of a knowledge by the author of the Hippocratic Writings or of the discoveries of the Alexandrian anatomists and surgeons, and it contains a number of things peculiar to itself and probably derived from ancient Indian traditions.

The translation of Susruta by Anna Moreshvar Kunte, of which the first numbers were published in Bombay in 1877, begins as follows:

"*Salutation to Brahma, Prajapati, the twin Asvins, Indra, Dhanvantari, Susruta, and others.*

"Now, hereafter, we shall narrate the chapter named the descent of knowledge (of medicine) just as it was taught to Susruta by the venerable Dhanvantari. Aupadhenava, Vaitarana, Aurabhra, Paushkalavata, Karavirya, Gopura, Rakshita, Susruta, and his other friends in earnest addressed the venerable Dhanvantari, the respected of gods (then known by the name of Divodasa), the descendant of Kasiraja, who was leading the life of a hermit, surrounded by a number of sages: 'Sire! we are moved with compassion, seeing human beings, though protected (by their kings), yet quite helpless, being afflicted with numerous bodily, mental, natural, and accidental maladies. We wish to be instructed in the Science of Medicine for the sake of public good, for earning our livelihood, and for allaying the sufferings of mankind desirous of health. Earthly and heavenly bliss depends upon it. Hence, Sire, we have come to you to become your pupils.'

"To them said the venerable man: 'Ye are welcome. All of you, my lads, shall be taught and made to meditate. Ayur-Veda is an Upanga of the Atharva-Veda. The Self-born, after creating the universe, composed it in a thousand chapters, containing a hundred thousand verses. But, knowing the brevity of human life and the limitedness of human understanding, he reduced it to eight divisions. These are: 1. Shalyam, splinter (extraction) surgery; 2, Shalakyam, inquiry into the disease of organs situated above the clavicles; 3, Kayachikitsa treats of diseases affecting the whole body; 4, Bhutavida treats of diseases of mind produced by demoniacal influences; 5, Koumarabhrityam, care and treatment of children; 6, Agadatantram, doctrine of antidotes; 7, Rasayanatantra, doctrine of elixirs; 8, Vajikaranatantram, rules for increasing the generative powers. Which of these do you wish to be taught?'—'Sire,' said they, 'teach us all, but begin with surgery first.'—'Be it so,' said he.—They again requested him, saying, 'Susruta, after consulting us all, shall ask you for explanations (in matters of doubt), and whilst he is made to understand we shall also try to do the same.'—'Well, then, my pupil, Susruta,' said he, 'the Science of Medicine has for its object the emancipation from disease of those who are afflicted by it, and the pres-

ervation of the health of those who possess it. Ayur-Veda is so called because by it health is gained or it brings health. The best portion of it I explain to you: try to follow me and judge by the four criteria of judgment—namely, inference, comparison, testimony, and perception. It is the best, because the first inflicted wound was healed (by its knowledge), and the head of Yajna was united to his trunk. It is said that when Rudra cut of the head of Yajna the gods went to the twin Asvins and said to them, "You two are of a higher rank amongst us. We entreat you to join together Yajna's head and trunk." They complied with the request. For their sake the gods propitiated Indra and allowed them a share in his sacrifice. They forthwith joined the head and trunk together. Of all the eight parts of which the Ayur-Veda is composed, this is the best, from the speediness of its operations, from its including the use of appliances, surgical instruments, caustics, cauteries, and from its being common to the other parts (of the science). Thus it is eternal, merit-giving, divine, leading to renown, longevity, and prosperity.

"'The great god Brahma announced (the knowledge of medicine) first; Prajapati learnt it from him; the twin Asvins got it from Prajapati; from them Indra; and from Indra have I learnt it. I am going to impart it to anybody who seeks it for the sake of public good.

"'On the preliminary preparations (rules to be observed before, during, and after the completion) of surgical operations:

"'Every action (to be successful) involves three stages—viz. 1, the preparatory stage; 2, the predominant stage; 3, the succeeding stage. We shall point out that the treatment of diseases has these three stages.

"'In this science the use of edged instruments is considered to be predominant. Hence we shall begin our description with it and its accessories. Edged instruments are used for eight purposes—viz. 1, amputating; 2, opening; 3, scarifying; 4, puncturing; 5, exploring; 6, drawing; 7, evacuating; and 8, sewing. A surgeon contemplating to operate in any of the above ways should first have ready the following: blunt instruments (forceps, etc.), sharp instruments, potential cauteries, virtual cauteries, catheters, horns, leeches, a dry gourd, a cauterizing needle, stuffing materials, strings, board, bandage, honey, ghee, fat, milk, oil, soothing decoctions, injections, lotions, fan, cold and warm water, a frying-pan, able, steady, and attached servants.

"'Then on a good day, having a good lunar influence and the auspicious influence of stars, after invoking blessings from the Brahmans and medical men, and propitiating the sacred fire with honey, rice, and water, let the patient be seated, who has taken very little food, offered sacrifices, and made ablutions, with his face toward the east. The surgeon should stand with his face toward him, and plunge his instrument after the proper incision until matter comes out, and withdraw it, avoiding vital parts, vessels, muscles, articulations, bones, and arteries. In the case of a large collection of matter the incision may be of the breadth of two or three fingers even.

"'Incisions are either long, wide, even, or uneven. An incision, whether long, broad, clean, or dependent, is always to be extolled when it suits (the purpose and) the occasion. Boldness, rapidity of action, sharp instruments, operation without trembling, fear, or doubt, are always

praiseworthy of the surgeon operating. . . . . The operations for moles, ascites, piles, calculus, fistula, and mouth diseases are to be performed on an empty stomach. . . . . The instruments should be so made that they should be of a good finish, strong, clean in appearance, with good handles, whether they be sharp or blunt.

"'Among these the Svastika instruments ought to be about nine inches long; their mouths should be respectively like those of a lion, tiger, wolf, hyena, bear, elephant, cat, hare, antelope, crow, heron, dog, jay, vulture, falcon, owl, kite, cock, crouch, the bee, rat, mouse, or bullock, each half being united to the other by a nail of the form of a lentil-seed, being bent inward at the handles like the elephant-driver's hook. These forceps are recommended for the extraction of splinters lodged in bones.

"'The tubular instruments are of a variety of kinds, having various uses, open at one end or both or having several foraminæ. They are used for removing obstructions from the great canals of the body, or for examination of diseases, or as suction-tubes, or for the easy application of remedies. Their lengths are always determined by the aperture of the canal whence the obstruction is to be removed or by the use to which they are to be applied.

"'The different tubular instruments which are used in fistula, hemorrhoids, polypi, sores, urethral injections, enemas, retention of urine, ascites, inhalation for cough and dyspnœa, and obstruction of bowels, together with the bottle-gourd and the horns, shall be described hereafter in their proper places.

"'The probe-like instruments are of various kinds and serve a variety of purposes. Their magnitudes differ according to the uses they are applied to. Among them the earthworm-like probe, the arrow probe, the serpent-hood probe, and the hook probe are each of them two in number. They have been recommended for sounding, separating, loosening, and extracting (foreign bodies). Probes having lentil-seedlike ends are two. They are slightly curved inward at their extremities, and are used for the extraction of foreign bodies from the large canals. There are six probes which are capped with cotton wool, and are used for cleaning and wiping purposes. There are three which are ladle-like and mortar-like, and are used for application of caustics. Three others there are which have their ends like a jambul-seed. Three others, again, resembling the elephant hook. These six are used for cauterizing purposes. There is a nasal-polypus probe which resembles the kolasthi. There is the inunction probe, which at its both extremities has a knob like the pea-seed, resembling an open bud. There is the urinary catheter, which resembles the stalk of malati- [*Jasminium glandiflora*] flower, and its length varies according to purpose. . . . .

"'The lion-mouth forceps is for foreign bodies that can be seen, while for covered ones there is the heron forceps and others of its kind. These should be used gently, the foreign body being removed in accordance with surgical precepts.

"'The heron forceps is the best of all forceps, since its use never leads to accidents. It enters easily and is very easily drawn back. It lays a firm hold on splinters and removes them easily.'"

No allusions are made to the use of the ligature, but amputations of

the limbs were performed, the hemorrhage being checked by the cautery, by boiling oil, and by pressure.

The operation of lithotomy is described, being that of "cutting on the gripe," the incision being made on either the left or the right side of the perineum, the breadth of a barley-corn from the central line and an inch from the anus.

The suprapubic operation was also known, rhinoplasty is described, and herniotomy is referred to. Manual skill was to be acquired by the student by making punctures and incisions on gourds and other fruits or on dead animals.

Fractures and dislocations are described with considerable detail of classification, and the bamboo splints recommended are still in use. The most original thing in the work is the part which relates to plastic surgery, and especially to rhinoplasty.

Of the history of surgery in China almost nothing is known. Hwa T'o, who is supposed to have lived in the third century A. D., is ordinarily considered to have been the father of surgery in China. He is said to have performed abdominal section for the local treatment of diseased viscera; to have laid bare the scapula of a certain great military hero and scraped from it certain poison, possibly carious bone; also to have relieved by acupuncture an affection of the brain of another famous general of his time. It does not appear that this was entirely successful, however, for he subsequently proposed trephining for the surgical cure of this disease, on which the indignant general is stated to have declared him a traitor who was plotting his death, and to have had him beheaded.

Ch'ăn Kwei in the sixth century A. D. is also said to have successfully removed certain diseased viscera by incision through the abdominal wall.

These stories rest upon no definite foundation. Acupuncture, counter-irritation, and various forms of shampooing seem to have been the only forms of surgical treatment practised in this nation, and operative surgery is now, as it probably always has been, practically unknown among the Chinese.

After the time of Hippocrates there is very little of interest from a surgical point of view recorded in Greece itself. His sons, Thessalus and Draco, and his son-in-law, Polybius, were also physicians, and are supposed to be the authors of some of the books in the Hippocratic collection. Aristotle gave a strong stimulus to the study of anatomy, and is said to have written two books on medicine, which have been lost. Through the influence of his pupils the famous library, museum, and schools of Alexandria were formed, and the headquarters of medical knowledge for the time being passed to Egypt. The Alexandrian School is famous for the advances in the knowledge of human anatomy which were made there as a result of the authority which was, for a short time, granted for the dissection of human bodies. The numerous writings of the anatomists of this school have been lost as distinct works, but probably all their important discoveries and teachings have been preserved for us in the works of Celsus, Galen, and Oribasius. Herophilus (about 300 B. C.) was perhaps the most famous of these anatomists, and many of the names of parts which he gave are in use to-day, such as the choroid, the retina, the dura and pia mater, the calamus scriptorius, the duodenum, and the prostate. Erasistratus, his contemporary and rival,

was also a famous anatomist, but we know even less of his work than we do of that of Herophilus. Galen says that he invented the catheter, but it is probable that this instrument was known both in Egypt and in India long before.

The advances in surgery made by the Alexandrian School prior to the Christian era are practically summed up in the first treatise on surgery written in Latin which has come down to us—namely, that of Celsus, or, more properly, of Aulus Cornelius Celsus. Of the personality of this writer we know nothing positively, but he probably lived at Rome about the beginning of the Christian era, and was not a physician by profession, medicine at that time being almost exclusively practised by Greeks. He is quoted by Pliny as an author as distinguished from a physician, and his work was not referred to by any medical writer for over a thousand years after his death. His book was a sort of encyclopædia of the arts and sciences of his time, intended for educated men, but not specially for physicians, and the medical portion consists of eight books or sections, which, in the original, followed the five books of the treatise on agriculture—the first book of the "De re Medica" being in the oldest Vatican manuscript entitled "Auli Cornelii Celsi liber sextus, idemque medicinæ primus." After the invention of printing the "De re medica" of Celsus was one of the first books that issued from the press, having been published in 1478, since which date there have been over sixty Latin editions and translations into most modern languages.

Most persons not familiar with the history of the art are accustomed to place Celsus with Hippocrates and Galen as one of the three great Fathers of Medicine; but he was really only a compiler, although a compiler whose conciseness and clearness of style have gained for him the title of "the Medical Cicero." As Greek was the professional language of his day, he could find no Latin equivalent for many of the technical terms, and was obliged to use either a descriptive periphrasis or to give the Greek word, introduced by the phrase "the Greeks call it." He was also troubled by the fact that in writing in Latin on the subject of hernia he was compelled to use what was considered to be a very immodest and improper word, for which he duly apologizes; and this is one of the numerous proofs that his work was not intended for physicians especially, but for the educated public.

A compiler without practical experience is sure to make some mistake; and a good illustration of this is found in the remarks of Celsus upon dislocation of the hip, as pointed out by Broca. Dislocation of the hip-joint, prior to the discovery of anæsthetics and the introduction of Reid's method, was often very difficult to reduce; but after it had once been reduced there was no special difficulty in keeping the head of the femur in its proper place. Celsus had probably never seen a case, but he had heard that one of the great dangers is that when reduced it may slip out again, this idea having probably arisen from confounding fracture of the neck of the femur with dislocation of its head; so he argues as follows: "Some maintain that it always does so [*i. e.* slips out again], but Hippocrates, Diocles, Philotinus, Nileus, and Heraclides the Tarentine, very celebrated authors, have asserted that they have effected a perfect cure. Neither would Hippocrates, Andreas, Nileus, Nympho-

dorus, Protarchus, Heraclides, and also a certain mechanician have invented so many kinds of machines for extending the femur in this case if it had been to no purpose. . . . . Therefore it must be attempted." The logic is excellent, but the point which he supposes to be in dispute is wholly imaginary.

Some of the details of surgical practice given by Celsus will be considered in connection with those found in other writers next to be referred to. Of these the chief is Claudius Galen, who was born at Pergamus 131 A. D. He studied medicine at the schools of Smyrna, Corinth, and Alexandria, and returned to Pergamus at the age of twenty-eight, when he was appointed to the medical charge of the athletes of the gymnasium connected with the temple of Æsculapius. Four years later he went to Rome, where he soon became celebrated. He finally returned to his native country, where he died when about seventy years old. He is said to have written five hundred treatises on medicine, but a large number of these have been lost, and a number which exist in manuscript have not been printed.

The medical system of Galen is happily compared by Daremberg to a tissue of which the Hippocratic Writings are the woof and those of Aristotle the warp. His anatomy is mainly contained in his treatise "De usu partium," the purpose of which treatise is to prove that all the organs of the body are arranged in the best possible manner and show the wisdom and care of Nature. After a few preliminary definitions he begins his third section as follows: "As man is the wisest of all animals, so the hands are the instruments which belong to a wise being. For man is not the wisest of animals because he has hands, so says Anaxagoras, but he has hands because he is the wisest, as says Aristotle, who judges very judiciously. In fact, it is not by his hands, but by his reason, that man has learned the arts. The hands are an instrument, as the lyre for the musician or the pincers for the blacksmith."

Between the time of Celsus and that of Galen there were three writers whose names should be mentioned in a sketch of ancient surgery, although their works have for the most part been lost—namely, Soranus of Ephesus, about 79–138 A. D., and Rufus of Ephesus, and Heliodorus, about the beginning of the second century. The treatise of Soranus on the diseases of women, edited and translated into Latin by Ermerius, was published in 1869, and his "De signis fracturarum" was published by Cocchius, with a translation, in 1754. A considerable part of his medical writings form the books ordinarily attributed to Cælius Aurelianus. Such works of Rufus as have been preserved were edited and translated into French by Daremberg, and published in 1879. Heliodorus lived at Rome in the time of Trajan, about the beginning of the second century A. D., and wrote a treatise on surgery, the fragments of which, preserved for us by Oribasius, indicate that he must have been a skilful surgeon, well acquainted with anatomy and with various modes of operating which have been proclaimed as marvellous in later days, such as the torsion of arteries, a particular mode of operating for the radical cure of hernia by excision of the sac, the excision of stricture of the urethra, etc.

After Galen, probably about the end of the third century, came a surgeon named Antyllus, who seems to have been a skilful operator and

an original writer, but of whose works we have only fragments preserved in the writings of Oribasius, a native of Pergamus, who was the physician and friend of the emperor Julian about the middle of the fourth century. Oribasius wrote a huge medical cyclopædia, which formed seventy books, of which over two-thirds have been lost, but what remains is of much interest in an historical point of view, because he copied literally, or nearly so, the text of the authors from whom he compiled, often giving their names, and in this way has preserved fragments of many works of which we have no other means of knowledge.

The next in time of the great medical compilers and encyclopædists is Ætius Amidenus, who lived in the early part of the sixth century, studied medicine in Alexandria, and practised at Constantinople, where he became famous. He wrote a work in four books, each containing four sections, which is known as the "Tetrabiblos." There are no translations into modern languages. It is an important work in the history of surgery, containing extracts from previous authors not found elsewhere, and it supplements, to some extent, what remains to us of Oribasius, as it contains copies of some of the lost sections of that writer. He describes charms and amulets, in which he had full faith, and he has been supposed to have been a Christian, because in extracting a bone he recommends the use of the following word-charm: "Bone, as Jesus Christ caused Lazarus to come out of the grave, as Jonah came out of the whale's belly, come out!"

Following Ætius, about the middle of the sixth century was Alexander of Tralles, a Lydian, who practised at Rome, and wrote a work on medicine in twelve books, the Greek text of which was first published at Paris in 1548. He was a Christian, and made use of amulets and incantations, of which he gives several specimens.

Paul of Ægina (Paulus Ægineta), the last of the Greek writers on medicine, lived in the early part of the seventh century and studied at Alexandria. His seven books are among the most famous of medical classics, and form a compend and abridgment of the medical literature of his day carefully selected and concisely expressed. His main source of information appears to have been the works of Oribasius. He does not pretend to any originality, as will be seen by the following extract from his preface: "It is not because the more ancient writers had omitted anything in the art that I have composed this work, but in order to give a continuous course of instruction; for, on the contrary, everything is handled by them properly and without any omissions, whereas the moderns have not only in the first place neglected the study of them, but have also blamed them for prolixity. . . . . To remember all the rules of the healing art and all the particular substances connected with it is exceedingly difficult, if not altogether impossible. On this account I have compiled this brief collection from the works of the ancients, and have set down little of my own, except a few things which I have seen and tried in the practice of the art." The sixth book is a system of operative surgery, the most complete of any which have come to us from before his time, and the source of most of the surgical treatises of Arabian authors. In it he never refers to Celsus, but often to Galen.

Having thus given a brief account of the principal Greek and Latin writers on surgery whose works are known to us, we may now consider

the progress in the art which had been made between the time of Hippocrates and that of Paul of Ægina, a period of about one thousand years.

First, as to hemorrhage from recent wounds, and more especially arterial hemorrhage. Upon this subject the Hippocratic Writings contain nothing. Celsus says (lib. v. cap. xxvi.): "If we fear the hemorrhage, the wound is to be filled with dry pledgets of lint, and a sponge squeezed out of cold water is to be applied and compressed with the hand. If the blood still issues, the lint must be changed frequently, and if dry lint does not succeed, it should be moistened with vinegar. Caustics should not be used, except in urgent cases, on account of the inflammation which follows their use. If compression, cold, and vinegar fail to stop the bleeding, the vessels which pour out the blood are to be seized and tied with two ligatures, one on each side of the wounded part, after which the vessels are to be divided between the ligatures, that they may retract and still have the openings closed. If the case does not admit of this, the actual cautery may be used." Celsus makes no reference here to any distinction between arterial and venous hemorrhage. In speaking of castration he says: "The veins and arteries must be secured by a ligature at the groin and divided behind it." This is the first mention of the ligature of blood-vessels in published literature: it was an invention of the Alexandrian School, and is said to have been introduced at Rome by Euelpistus, who lived a short time before Celsus.

Galen refers in several places to the use of the ligature, but treats more especially of hemorrhage in the fifth book of the Methodus Medendi. He directs that the finger be placed gently upon the mouth of the bleeding vessel, extending and compressing it. If the wounded vessel lies deep, the surgeon must thus learn its position and size, and then, whether it be a vein or an artery, lift it with a hook and twist it a little. If this does not answer and it is a vein, styptics, such as roasted rosin, fine flour, gypsum, etc., are to be tried; but if it is an artery, it must be either ligated or entirely divided. Sometimes the veins must also be ligated and divided; but it is safer to do both—that is, to ligate the proximal end of the vessel and also to divide it beyond the ligature. Oribasius says nothing about the ligature, but advises the cautery if the bleeding cannot be checked otherwise. Paulus Ægineta copies Galen almost literally, but says, in addition: "You may know whether it is a vein or an artery that pours forth the blood from this, that the blood of an artery is brighter and thinner and is evacuated by pulsations, whereas that of the vein is blacker and without pulsation."

While it is thus evident that the use of the ligature was known from the beginning of the Christian era, it is curious that it seems never to have been employed to check hemorrhage from vessels divided in amputations.

Celsus remarks that in cases of gangrene of an extremity the incision is to be made between the sound and the corrupted part, but says nothing about details. Galen's advice is the same as that of Hippocrates. Paulus says: "Leonides properly directs us not to divide all the parts at once unless they are completely mortified, but first to cut the part where not many nor very large veins or arteries are known to be situated, down to the bone quickly; then to saw the bone as rapidly as possible, applying a linen rag to the parts which have been cut, lest they be torn by the

sawing and cause pain, and then, having cut through what remains, to apply red-hot irons to the vessels, and stop the hemorrhage thereby with compresses of lint." The Leonides referred to here was an Alexandrian surgeon who lived about the beginning of the third century A. D. Prior to this, however, Archigenes, a celebrated physician who lived at Rome about the beginning of the second century A. D., and Heliodorus, had given more details as to methods of amputation, as appears from the fragments of their works preserved in the collection of Nicetas, published by Cocchius in 1756. Archigenes appears to have commenced the operation in some cases by a preliminary ligature of the blood-vessels supplying the parts; the incision was a circular sweep down to the bone. The red-hot iron was used to check hemorrhage. The method of Heliodorus is substantially the same as that of Leonides.

Aneurism is not mentioned by Hippocrates or by Celsus. Galen describes it in his work "De tumoribus," saying that it may arise either from simple dilatation or from a wound of an artery, and is recognized by its pulsation. The only treatment he refers to is compression by means of sponge.

The following is an extract from the treatise of Antyllus on aneurism, as given by Oribasius: "There are two kinds of aneurysm. In the first the artery has undergone a local dilatation; in the second the artery has been ruptured. The aneurysms which are due to dilatation are longer than the others. The aneurysms by rupture are more rounded. To refuse to treat any aneurysm, as the ancient surgeons advised, is unwise; but it is also dangerous to operate upon all of them. We should refuse, therefore, to treat aneurysms which are situated in the axilla, in the groin, and in the neck, by reason of the volume of the vessels and the impossibility and danger of isolating and tying them. We should not touch an aneurysm of large volume even when it is situated in some other part of the body. We operate in the following manner upon those which are situated upon the extremities and the head: If the aneurysm be by dilatation, make a straight incision through the skin in the direction of the length of the vessel, and, drawing open by the aid of hooks the lips of the wound, divide with precautions the membranes which cover the artery. With blunt hooks we isolate the vein from the artery, and lay bare on all sides the dilated part of this last vessel. After having introduced beneath the artery a probe, we raise the tumor and pass along the probe a needle armed with a double thread in such a manner that this thread finds itself placed beneath the artery; cut the threads near the extremity of the needle, so that there will be two threads having four ends; seizing, then, the two ends of one of these threads, we bring it gently toward one of the two extremities of the aneurysm, tying it carefully; in like manner also we bring the other thread toward the opposite extremity, and in this place tie the artery. Thus the whole aneurysm is between the two ligatures. We open then the middle of the tumor by a small incision: in this manner all which it contains will be evacuated, and there will be no danger of hemorrhage.

"To tie, as it has been advised, the artery on both sides the vein, and then to extirpate the dilated part which finds itself between, is a dangerous operation; frequently, in fact, the violence and tension of the arterial pneuma push off the ligatures.

"If the aneurysm owes its origin to the rupture of the artery, we isolate with the fingers as much of the tumor as we can, including the skin, after which we pass underneath the isolated part the needle with the double thread and proceed as before; after which the tumor may be opened at its summit and the superfluous portion of the skin cut away."

Upon injuries of the skull and trephining Celsus speaks at considerable length, quoting fully from Hippocrates. To distinguish a fissure from a suture he advises the pouring of ink on the part and then scraping the bone; if there is a fissure, the ink will mark it. He says that if blood is extravasated beneath the cranium, the overlying bone will be pale. If no dangerous symptoms come on, he would defer operating on the bone for five days. All depressed bone is to be removed, but no more is to be taken away than is necessary. Galen preferred the use of small gouges, and of an instrument called a lenticular, to that of the trephine. He says that all greatly bruised (and depressed) bone is to be removed, but that simple fissures do not require operation. Paulus copies Galen. It will be seen that the Greek and Roman methods did not differ greatly from those of the present day.

In fractures of the spine Paulus says that, "having first given warning of the danger, we must, if possible, attempt to extract by an incision the compressing bone," and that the same is to be done in case of fracture of one of the spinous processes.

Celsus (lib. v. cap. xxviii.) describes carcinoma as usually occurring about the face, and in the breasts of females, but says that it may also occur in the liver or spleen. It is the seat of some lancinating pains, is tumefied, immovable, and unequal, and the veins about it are swollen and tortuous. It commences by what the Greeks call cacoethes, then proceeds to carcinoma or scirrhus without ulceration, then to an ulcer which becomes fungous. "None of these can be removed except the cacoethes; the rest are aggravated by every method of treatment, and the more energetic the remedies the more irritable they become. . . . . None were ever treated successfully with medicine; . . . . after excision, though a cicatrix has been formed, they have returned again and carried off the patient. . . . . But no one can distinguish a cacoethes, which is curable, from a carcinoma, which is incurable, except by time and experiment."

Galen describes cancer at greater length, but adds nothing to the means of diagnosis: the only chance of cure lies in excision, but if this be performed the arteries must not be tied.

Paulus merely abridges Galen's description, says nothing about an operation, and advises external applications. A hard tumor which is wholly insensible is incurable.

Cystic tumors, including atheroma, meliceris, and steatoma, are briefly but clearly described by Celsus (lib. vii. cap. vi.); they are to be removed by incision: in steatoma the cyst must be divided, in the others it may be removed entire. Antyllus gives a more detailed description, which is quoted by Oribasius (lib. xlv.).

The Hippocratic oath requires that lithotomy be left to those who make a special business of it. The first author who describes the operation is Celsus (lib. vii. cap. xxvi.). He says it should only be performed in the spring, and on children between the ages of nine and fourteen, and

in urgent cases when medicines have failed, although he admits that a rash operation now and then succeeds. The operation described is that which is commonly known as "cutting on the gripe," or, in modern times, as the "Celsian operation." The description given by Celsus is detailed, and in most points is very clear (lib. vii. cap. xxvi.). The essential principle is to force the stone down into the neck of the bladder and hold it there by two fingers introduced into the rectum, after which a lunated incision is to be made through the skin of the perineum immediately over and extending to the neck of the bladder, and a second incision in the convex part of the wound, so as to open the neck of the bladder freely; and the wound should be a little larger than the calculus, for those who dread a fistula make too small an opening, and are afterward reduced to the same inconvenience with still greater danger, because the calculus when forced will make a passage unless it find one; and this is even still more injurious if the form and inequalities of surface have contributed in any way to this effect. If the stone is so large that it cannot be extracted without lacerating the neck of the bladder, it must be split according to the method of Ammonius, who was known as Lithotomus, the stone-cutter. It is done in this manner: A crotchet is introduced to the calculus, so as to hold it fast while being struck, lest it should recoil backward; then an iron instrument of moderate thickness is to be employed, the one extremity of which is thin, but blunt, and being applied to the stone and struck at the other extremity, splits it, great care being taken that neither the instrument itself nor any fragment of the stone should injure any part.

There is practically nothing to add to this description by other Greek writers until we come to the time of Paulus, whose description is much the same as that of Celsus. He says that children up to the age of fourteen are the best subjects for the operation: old men are difficult to cure, because ulcers of their body do not readily heal, and intermediate ages have an intermediate chance of recovery. The stone is to be brought down by the fingers in the rectum, as described above; then "we take the instrument called a lithotome, and between the anus and the testicles —not, however, in the middle of the perineum, but on one side, toward the left buttock—we make an oblique incision, cutting down direct upon the stone where it protrudes, so that the external incision may be wider, but the internal not larger than just to allow the stone to fall through it. Sometimes, from the pressure of the finger or fingers at the anus, the stone starts out readily at the same time that the incision is made, without requiring extraction; but if it does not start out of itself, we must extract it with the forceps called the stone-extractor." . . . . "If the stone, being small, fall into the penis and cannot be voided with the urine, we may draw the prepuce strongly forward and bind it at the extremity of the glans. We must next apply another ligature round the penis behind the member, making the constriction at its extremity next the bladder, and then make an incision down upon the stone, and, bending the penis, we eject the stone, and undoing the ligatures we clear away the coagula from the wound. The posterior ligature is applied lest the calculus should retreat backward, and the anterior in order that, when untied after the extraction of the stone, the skin of the prepuce may slide backward and cover the incision."

After the capture of Alexandria by the newly-risen Mohammedan power, about 640 A. D., the Arabians became the inheritors and preservers of the science of the Greeks. The first notions of medicine obtained by the Arabs were probably derived from Persia, if we may judge by the names of a great number of their drugs, and the medical knowledge of Persia came in part from India and in part from Greece.

The first Arab physician of note was Hareto Ben Coladoh, who lived about the middle of the sixth century, and who seems to have studied medicine under the Nestorians, a Christian sect dating from the early part of the fifth century and occupying the ancient countries of Assyria and Persia. The Nestorian physicians appear to have been very zealous in collecting and preserving all the medical works which could be found at that time, including those of the Hippocratic collection and the writers of the Alexandrian School. In the mean time, after the destruction of Jerusalem, certain Jewish physicians and teachers had settled in Alexandria, and after the fall of that city we find some of these Jewish physicians taking somewhat prominent positions and being collectors and translators of the medical literature of the Greeks. The so-called "Arabic books on medicine" were largely compends and summaries of the works of Greek writers which had been translated into Syriac or into Hebrew, and thence into Arabic, or, in some few cases, directly into Arabic. There are very few of these which contain any matter of interest to the history of surgery.

The most famous of their writers was Avicenna (980–1036 A. D.), a native of Persia, who for five hundred years rivalled Galen as an authority and, like him, was called the Prince of Physicians. The medical works of Avicenna, known as "The Canon," are a sort of encyclopædia, in which the opinions of the Greeks and of Galen are mingled with Oriental philosophy, forming a very prolix and in many places obscure treatise upon all subjects connected with medicine. It was translated into Latin by Gerard of Cremona, and became for a time the principal guide for European physicians, its high repute being probably due in part to the difficulty of understanding it.

The most celebrated writer on surgery of the Arabian School was Albucasis, also known as Bulchasis, Abulcasis, or Alsaharavius, and properly as "Khalaf Ibn 'Abbás (Abu Al-Kásim) Al-Zahráwi." He was born at Zahra, near Cordova, and died about 1105 A. D. His great work, Al Tesrif or Tasrif—*i. e.* the collection or encyclopædia—included thirty books upon all branches of medicine, but of these only a part have ever been published. The three books of his works on surgery, forming a special treatise (book xxx. of Al Tesrif), were published in Arabic and Latin under the editorship of John Channing at Oxford in 1778, and this is the best printed edition which is available, although in some respects it is obscure and unsatisfactory. A translation into French was made by Dr. Leclerc and published in the *Gazette médicale de l'Algérie* in 1858–61, and afterward issued as a reprint (Paris, 1861); and this is the most convenient edition to consult for most purposes.

The work is divided into three books. The first is devoted to the actual cautery and the use of caustics, with elaborate descriptions of the instruments which are figured. In fact, Albucasis is the first author whose works have come down to us who has given figures and good

descriptions of surgical instruments. The second book relates to incisions of all kinds, bloodletting, scarification, treatment of wounds, and the extraction of arrows and missiles, and the third is devoted to the treatment of fractures, luxations, sprains, etc.

The treatise in general is a clear and comparatively concise statement of methods of treatment. A large part of it is evidently derived from Paul of Ægina or from the original authorities from which Paul of Ægina copied, and it is hard to say how much of his work is really original; but it was the highest authority on the subjects of which it treats during the period of the revival of letters in Western Europe, and is a very important work for the student of the history of surgery or of surgical operations. The following are some specimens of his teachings:

In speaking of the operation of arteriotomy upon the temporal arteries he directs that a portion of the vessel be cut out, so that the two ends may separate in order to prevent hemorrhage. If the artery is large, it is necessary to tie it in two places—at two points—with a strong double thread of silk or of the cord used in instruments of music (catgut), in order that it may not alter before cicatrization takes place, which would bring on a hemorrhage. This ligature should be double, and the operator is to take away the intermediate part, either at the time or later.

In speaking of the operation on scrofulous tumors of the neck he says: "The tumor must be removed little by little, great care being taken not to cut the blood-vessels or the nerves. If a vein or an artery is injured, so that the hemorrhage is troublesome or hinders the operation, put into the wound some vitriol in powder or some kind of hæmostatic powder; bandage the wound, and leave it until the inflammation lessens and the wound tends to putrefaction. Then the hemorrhage will cease and you may go on to complete your operation."

He says: "The ancients have spoken of opening the trachea, but I have not known any one in our country who has practised this operation. If the operation has been decided upon, the incision should be made below the third or fourth ring of the trachea transversely between the two rings, so as not to injure the cartilages, but only to divide the membrane between the rings. I have seen a slave who had cut his throat with a knife. On examining the wound a little blood escaped, but I found that neither the jugular vein nor the artery had been injured. The air came out by the wound; I dressed it and he was cured, and only a little hoarseness of voice followed. I feel, therefore, authorized to say that incision of the trachea is without danger."

In speaking of aneurism he says: "As to the tumors which result from the enlargement of the calibre of the artery, a longitudinal incision should be made over the skin. Enlarge the opening with hooks, dissect the artery, free it from the membranes which surround it, and lay it completely bare; then introduce below it a needle with a double thread and make a double ligature of the vessel, as we have recommended for the excision of the temporal artery; then plunge a knife into the part of the vessel included between the two ligatures, and press out all the blood which is contained therein, until the tumor has disappeared, employing after this the treatment which leads to suppuration until

the ligatures fall." It will be seen that this is a copy of the description of the operation of Antyllus.

In speaking of the removal of certain fungoid abdominal tumors resembling mushrooms he directs that a leaden wire be used to strangle the growths, the wire being drawn tighter and tighter from day to day so as gradually to penetrate the root of the tumor, so that it may fall without difficulty. He says: "Refrain from attempting to excise tumors which are of a livid color, of slight sensibility, and of an irregular aspect for these tumors are cancerous." Elsewhere he says: "If the cancer is situated in a region from which it can be entirely removed, such as the breast, the thigh, etc., and, above all, if it has had its commencement little developed, one may operate on it; if, on the contrary, it is large and old, it is necessary to refrain. For my part, I have never been able to cure a single one. I have never seen any one who has succeeded."

His description of the operation of the removal of calculus of the bladder is substantially the same as that given by Celsus.

In the case of a vesical calculus in a woman he says that if you are obliged to treat such a case, you must find a woman with some skill in medicine, but there are very few of them. If you cannot find such, it is necessary to take a midwife, or, at all events, a woman who knows a little something about the matter. This woman is to perform the operation under the direction of the surgeon, according to the method which he gives in detail.

While the arts and sciences were more or less prosperous and progressive in the countries under Mohammedan rule, and especially in Spain, throughout the rest of Europe medicine was substantially in the condition in which it exists in barbarous tribes. With the rise of the monkish orders, and especially of the order of St. Benedict, the priests became the practitioners, and all progress or improvement was practically at an end. Relics, exorcisms, and prayers were more and more relied upon; the teachings of Hippocrates and Galen were for the most part forgotten. The great majority of the monks read nothing but simple formularies and receipt-books. The kings and the great nobles, including some of the bishops, resorted to Hebrew physicians, who during the tenth and eleventh centuries were almost the only persons who possessed medical learning or who wrote upon medical subjects. A Jewish physician in those days was a sort of contraband luxury. On account of his religion he could only be possessed by those who had sufficient power to protect him from mobs and monks; but both Catholic and Mohammedan rulers resorted to him when anything like scientific knowledge was required. Rabbi Isaac was the medical adviser of Pope Boniface VIII., and the physician of Saladin was Rabbi Ben-Moosa, better known as Moses Maimonides, who was one of the most celebrated authors of his race and time (1136–1209 A. D.). It should be noted that the preference was for Jewish physicians as being Jews. For instance, Francis I., being sick, wrote to Charles V. for an Israelite who was an imperial physician. Accordingly, the doctor was sent to Paris, but Francis, finding that he had been converted to Christianity, lost all confidence in his skill and advice, and applied to Solyman II., who sent him a true, original, hardened Jew, following whose advice he drank asses' milk and recovered.

Surgery was for the most part abandoned to barbers, bathers, and seventh sons, and fell into disrepute. These barbers and bathers were considered to be of inferior caste, and an artisan would not take an apprentice of a family of barbers, bath-keepers, shepherds, or butchers. The operators were often peripatetic and were subdivided into specialists. For instance, one operated for hernia, another for calculus, a third for cataract, etc., the knowledge being handed down from father to son, as among the Greeks.

There were no European writers upon, or teachers of, surgery until the time of the rise of the universities in Italy in the thirteenth century. The School of Salernum was probably in existence in the ninth century, the ancient legend being that it was founded by four men—a Jew, a Greek, an Arab, and an Italian—each of whom gave lessons in his own language.

About the year 1060 A. D. there came to this school a certain Constantine, generally known as "Constantinus Africanus." Constantine was a native of Carthage, and had studied in Arabia, India, and Egypt, after which he travelled extensively for over thirty years. Returning to Carthage and bringing with him copies of all the works of the Greek and Arab writers which he had been able to obtain in his travels, he fell under the suspicion of knowing more than it was at that time considered proper for any man to know, and it was with some difficulty that he escaped the punishment then in vogue for such criminals. He fled for refuge to Salernum, where he was received with honors, which, however, he put aside, and retired to the neighboring monastery of Monte Casino, where he spent the rest of his life in translating and annotating the medical works which he had collected. These translations became the text-books of the Salernitan doctors, and in the next century the school was resorted to from all parts of Europe by those who had heard of these long-lost and forgotten treasures of learning, which at that time were far in advance of the existing knowledge of the ordinary practitioners.[1]

The doctrines of the school became more and more Arabic, and it had lost its importance in the fourteenth century, having been superseded by the schools of Naples, Bologna, Paris, and Montpellier.

At the beginning of the thirteenth century comes the first writer on surgery in the West—namely, Roger of Parma, whose work was first printed at Venice in 1490, and is included in several editions of the works of Guy de Chauliac. The Surgery of Roger is substantially the sixth book of Paul of Ægina. Following him came his pupil and commentator, Roland, who was also of Parma. His work is a copy of that of Roger, with notes and some references to Hippocrates, Galen, and Avicenna which do not appear in the work of his master.

The story of the Four Masters, as told by Quesnay, is a romantic one—*i. e.* that they devoted their lives to the care of the sick poor in Paris, their residence being a sort of surgical dispensary; that they made many discoveries and improvements which they described in a book which was known to Guy de Chauliac, but has been lost; etc. Several

[1] For a full and interesting discussion of the writings of Constantine and the authors copied and abridged by him, consult "Constantinus Africanus und seine Arabischen Quellen," von M. Steinschneider, *Archiv f. path. Anat.* (Virchow), 1866, vol. xxxvii. p. 361.

manuscript copies of this work are now known to exist, and in 1859 one of these was edited by Daremberg and published.

The history of surgery in Europe thus begins in Italy at Salernum, and in Bologna, where Hugo of Lucca flourished during the first half of the thirteenth century, and was followed by William of Salicet. We have no writings from Hugo, but the *Cyrurgia* of William remains to us. The first edition of the original Latin was published at Placentia in 1476, and this, with other editions, including French translations (Lyons, 1492, and Paris, 1507) and an Italian translation published at Milan in 1504, is in the Army Medical Library at Washington.

William of Salicet was the most celebrated surgeon of his century; he was an educated physician, who gives some of his own observations and his own conclusions, hardly citing previous authors, although it is evident that he was familiar with the works of Avicenna and of Galen. It is a pity that the *Cyrurgia* has never been translated into English.

The next noted surgeon of this period is Lanfranc of Milan, a pupil of William of Salicet, to whom he refers as his "master of goodly memory." Lanfranc also received a university education, and was a physician as well as a surgeon. Political troubles having caused his banishment from Milan, he went first to Lyons, where he wrote an epitome of surgery, and finally in 1295 to Paris, where he gave, at the School of Medicine, a course of lectures which were probably embodied in his great Surgery, which he completed in 1296. He was thus the introducer of the new Italian ideas into France. His large work was first published at Venice in 1490 under the title *Practica quæ dicitur ars completa totius Chirurgiæ.*" In the same year a French translation by Guillaume Yvoire was published at Lyons, and of this there is a copy in the Bibliothèque Nationale at Paris.

After Lanfranc came Henri de Mondeville, a native of Normandy, of whose early life nothing is known except that he studied at Montpellier, and at Paris under Jean Pitard, who will be referred to hereafter, and that he was one of the four surgeons of the court of Philip the Fair prior to 1301. In 1306, at the request, as he says, of Bernard de Gordon, a distinguished professor of Montpellier, he began to write, and to read to his numerous pupils, a systematic treatise on surgery, which he did not complete, although he lived until about 1318. This treatise, of which several manuscripts exist, was finally edited and printed by Dr. Julius Leopold Pagel of Berlin in 1892, forming an octavo volume of 660 pages having the title of *Die Chirurgie des Heinrich von Mondeville (Hermondaville), etc.*, and has been translated into French and published in 1893 by Professor Nicaise of the Faculty of Medicine of Paris. His practice is much the same as that of Lanfranc, and of his successor, Guy de Chauliac, who often quotes him. He describes the method of ligating a wounded artery, recommending a peculiar kind of slipknot, but says nothing of ligating the vessel in amputations, and refers to the use of the anæsthetic sponge described by Guy.

Here may also be mentioned the Surgery of Master Jean Yperman, a native of Flanders, who was born in the latter part of the thirteenth century and studied under Lanfranc in Paris. The manuscript of his book, dated 1351, was first described, and in part published, by Dr. Carolus in the *Annales de la Société de Médecine de Gand* (vol. xxxii.

1854); also published separately as a reprint. He refers to Roger and Roland and the Four Masters, and frequently to Lanfranc, beyond whose teachings he seldom ventures to go, although he does give some cases of his own.

The great French surgical author of the fourteenth century was Gui (or, as it is more usually given, Guy) de Chauliac, "Guido de Chauliaco," born about 1300 A. D. He received the university training of the clerical profession and studied medicine at Paris, after which he continued this study at Montpellier and Bologna, so that he had the benefit of the three greatest universities of that time—Paris being especially celebrated for its surgery after Lanfranc had reached it; Montpellier being the centre for medicine; and Bologna for anatomy, of which Bertrucius was then professor. After extensive travels, and practice in different places, including Lyons and Montpellier, he went to Avignon and became the physician of Pope Clement VI. and of his successors, Innocent VI. and Urban V. His chief literary work was his *Chirurgia*, written at Avignon in 1363, and first published at Lyons by Nicholas Panis in 1478.

The "Great Surgery" begins with a special introductory chapter, the *chapitre singulier*. He says: "Up to the time of Avicenna all writers were both physicians and surgeons (*i. e.* well-educated men), but since that time, either because of the fastidiousness or the excessive occupation of the clerics, surgery has become a separate branch and has fallen into the hands of the mechanics.

"The sects which have existed in my time among the operators of this art, besides the two general ones of the Logicians and the Empirics, have been five.

"The first was the school of Roger, Roland, and the Four Masters, who treat all wounds and abscesses alike with cataplasms and poultices, on the ground of the fifth aphorism, 'Lax things are good, and crude bad.'

"The second was the school of Bruno and Theodoric, which treated all wounds alike with wine, basing their practice exclusively upon the maxim, 'The dry is nearest to that which is sound, and the moist to that which is not sound.'

"The third sect was that of William of Salicet and of Lanfranc, who wished to pursue the middle course, covering and dressing all wounds with ointments and soft plasters, founding this practice on the fourteenth maxim of the Therapeutics—that curation has one sole method; that the treatment should be gentle and without pain.

"The fourth sect is composed of all the military men, or German chevaliers and others following the army, who, with conjurations and potions, oil, wool, and cabbage-leaves, dress all wounds, basing their practice on the maxim that God has given his virtue to herbs and to stones.

"The fifth sect is of women and of many fools, who refer the sick of all diseases to the saints solely, saying, 'Le Seigneur me l'a donnee ainsi qu'il luy a plû; le Seigneur me l'ostera quand il luy plaira; le nom du Seigneur soit benit. Amen.'"

It will be seen that Guy is quite trenchant in his summaries and criticisms, which, however, appear to be on the whole fair and justifiable.

The teachings of Guy were the chief authority in surgical matters

for over two hundred years, and were the basis of numerous abstract compends, and commentaries. He contributed little that was origina although he gives some of his own observations. Follin remarks that sort of canulated sound, the dressing of ulcers with sheet lead, and son peculiarly-shaped cauteries are his chief inventions; but his book is or of the monuments of surgical literature.

The *Sermo septimus de cyrurgia et de decoratione* of Nicholas Falcu tius, of which the Washington Library has an edition printed at Floren in 1507, is a huge folio volume compiled from the works of Arab writer with references to Roger and Roland, but not to Guy de Chauliac, so f as I have found. His formula of words is "Dixit Haly," or "Avicen or "Albucasis," without attempt at comment.

In the days of Lanfranc and Guy de Chauliac surgery in Weste Europe was distinct from medicine, and was looked upon as a trade handicraft degrading to and unworthy of physicians, who claimed belong to the nobility. The physicians were of the priestly class ar abhorred the shedding of blood, and their traditions were adhered to lo after medical teaching in the universities had passed into the hands laymen. The barbers were the ordinary surgical operators, and the reas for this is given by Dr. Gardner[1] as follows: "The monks, as all t world knows, required to have their heads regularly shaved, but it is n by any means so well known that they had to be bled at stated perio *Minutus est* was the form of words descriptive of one who had undergo the operation, the meaning being that he had been *minutus sanguine- i. e.* deprived of blood. In the monastery of St. Victor at Paris the was an order which prescribed such minution five times a year: 'Prim est Septembri; secunda, ante Adventum; tertia, ante Quadrigesimu quarta, post Pascha; quinta, post Pentacosta.' The monks, therefo required to have about them those who could both shave and bleed, a it was very natural that they should prefer that one and the same pers should perform both these operations."

In France, however, at an early date there were a few persons wh business was the performance of surgical operations, and who were n ordinary barbers, although they may have served an apprenticeship such. The Corporation of Barbers in the middle of the thirteenth ce tury was divided into two classes—the ordinary or lay barbers, afterwa known as "barber surgeons" or "surgeons of the short robe," and t "clerk barbers" or "surgeon barbers," "the surgeons of St. Côme," "surgeons of the long robe;" and these last sought to be independe of the ordinary barbers, to monopolize surgical operations, and to ra their association from the position of a trade guild to that of a prof sional organization. The Guild of the Surgeon Barbers was organized 1268 by an order of the provost of Paris, selecting six surgeons w were to examine and license those who wished to practise, more especial the barbers. Possibly one of these masters was the celebrated Jean Pita but if so he must have been very young, for he was still living in 13 In 1311, Pitard obtained a decree from King Philip the Fair, in whi after reciting that all sorts of quacks are infesting the city, it is order that "no male or female shall practise surgery in Paris who has not be

[1] Gardner (John): *Sketch of the Early History of the Medical Profession in Edinbu* Edinb., 1864, p. 6.

examined by our sworn surgeons of Paris named and called together for that purpose by Jean Pitard, our sworn surgeon of the Châtelet, or his successors."

It was evidently impossible to enforce this order, for it was repeated in 1352, and again in 1364, with penalties of fines on the erring barbers, half of the fines to go to the surgeons' guild, the Brotherhood of St. Côme. The organization of this brotherhood was by no means pleasing to the medical faculty, the members of which desired to retain control of all branches of the art, and discredited surgery as a mere mechanical handicraft only to be exercised under the direction of a physician, whose dignity forbade him to soil his hands. The statutes of the faculty in 1350 require the candidates to make oath that they will not practise surgery in the sensé of performing operations or making applications by the hands, including the treatment of five classes of affections—viz. wounds, ulcers, fractures, dislocations, and tumors.

The lay barbers were employed by the physicians, and also sometimes as assistants by the surgeons, and at last, in 1372, the barber of the king, being the master of the guild of barbers by virtue of his position, induced Charles V. to issue an edict which permitted them to treat wounds and sores and forbade the surgeons to interfere with them. The relative standing in the eyes of the public of the three kinds of practitioners—viz. the physicians, the surgeons, and the barbers—may be inferred from an order issued during an epidemic of the pest in 1383, which directed that there shall be selected to visit the sick four physicians, two surgeons, and six barbers, and the fees of the doctors shall be three hundred livres, of the surgeons one hundred and twenty livres, and of the barbers eighty livres.

The so-called College of Surgeons of Paris was not in the least a surgical school or an association for mutual discussion and improvement: it was purely a trade guild, and the students were simply apprentices to the master surgeons, becoming, after 1370, bachelors, licentiates, and finally masters. The surgeons had a free dispensary, where they treated the poor once a week, and perhaps the apprentices saw there something of the practice of other masters besides their own.

The medical faculty, thinking that its rights, privileges, and monopoly of treating the sick were being encroached upon by the surgeons, encouraged the barbers in their controversies, and as one means of doing this undertook to teach them anatomy. As the barbers did not understand Latin, which was the only dignified and proper language to be used in teaching in those days, a compromise was necessary, and this was effected partly by the use of a sort of dog-Latin, of French words with Latin terminations, and partly by reading Guy de Chauliac in Latin, but with comments in French, while the assistant barber made the incisions in the cadaver and pointed out the parts as the reader named them. In 1505 the barbers came more formally under the protection and jurisdiction of the faculty, and assumed the name of the Guild of the Barber Surgeons, and a few years later the surgeons of the long robe, having opposed this movement with very little success, and having failed to become a separate faculty in the university, submitted to also receive instructions from the physicians. Almost all the medical officers attached to the French armies came from the Corporation of Barber

Surgeons, and finally one of them, Ambrose Paré, acquired so muc reputation and influence as to considerably increase the respectabilit and standing of the guild. As a sample of surgical associations in th provinces we may take the surgeons of Bordeaux, who in 1519 forme a society composed of *béjaunes* (yellow beaks or young birds—*i.* aspirants) and companions. They had a password and special secrets instruction was given in the winter at 5 A. M. in the form of commen taries on Guy de Chauliac, and in the course of one hundred and sixty nine years five bodies were dissected.[1]

There is little of importance in the history of surgery during th next hundred years after the death of Guy de Chauliac. Peter o Argelata, lecturer on surgery at Bologna about the beginning of th fifteenth century and dying in 1423, was the principal surgeon of hi time. His six books on surgery, edited by Moretus, first published a Venice in 1480, are largely derived from Paulus and Guy. He was a operator as well as a theoretical teacher, performed lithotomy and her niotomy, embalmed Pope Alexander VI., practised craniotomy of th fœtus in difficult labors, etc. A copy of his books was annotated o the margins by Marcellus Cumanus, a surgeon in the Venetian arm in 1495, and these observations were finally published by Velschiu (G. H.) in his *Sylloge Curationum* (Aug. Vindel., 1668). Cumanu found nothing in Argelata about the treatment of gunshot wounds, an he noted a formula for this purpose consisting of a mixture of oil o roses, galbanum, and asafœtida, to be applied hot.

Gunpowder was used in warfare at least as early as 1338; the Englis employed it at the battle of Crecy in 1346, but it was a long time befor any surgeon published an account of gunshot injuries and their treatment The first Italian surgeon to do this was John de Vigo (1460–152–), sur geon of Pope Julius II. in 1503, whose *Practica in Arte Chirurgic Copiosa* was first published at Rome in 1514. This book had twenty one editions in thirty years, and was translated into Italian, Frenc English, Spanish, Dutch, German, and Portuguese. The great succes of the book was due partly to the fact that it was the first complet system of surgery issued after that of Guy de Chauliac, partly to th fact that it contained an account of gunshot wounds and a section on th new disease, syphilis, and also, probably, to a considerable degree, becaus it was a book which specially suited a practitioner who knew nothing o anatomy and feared or disliked to make use of the knife. It is essen tially a surgery of plasters, ointments, and embrocations, and the nam of the author is best known to-day in connection with the "emplastru de Vigo."

The part relating to gunshot wounds is brief. He says they are con tused and burned, and therefore need moist applications, but that the are also poisoned by the powder, and therefore need desiccation; henc they are hard to cure. They are to be cauterized with the actual cauter or with boiling oil of elder, "for cauterization kepeth the wounde fro putrefyinge."

His chapter on syphilis begins as follows (I use the English transla tion of 1543): "In the yeare of our Lord 1494, in the moneth o December, when Charles the Frenche kynge toke hys jorney into th

[1] Sous (G.): *Bordeaux médicale*, 1877, p. 49.

partes of Ytaly to recover the kyngdome of Naples, there appeared a certaine dysease throughout al Ytaly of unknowen nature, which sondre nations hath called by sondry names. The French men call it the dysease of Naples, because the souldyours brought it from thence into France. The Neapolitanes call it the Frenche dysease."

Controversies as to whether syphilis existed prior to the fifteenth century have been many, and the literature on the subject is voluminous; but no positive and convincing proofs of such existence have yet been found, although it is probable that it did occur before that time. One of the theories of its origin, advanced first by Leonard Schmaus in the preface to his little pamphlet, *Lucubratiuncula de morbo gallico et cura ejus noviter reperta cum ligno indico* (sm. 4°, Aug. Vindel., 1518), is that it was brought from the West Indies by the sailors who returned with Columbus after his first voyage, and attempts have been made to furnish positive evidence of this from human bones showing evidence of disease, and antedating the Columbian discovery; but none of these have been convincing to skilled pathologists. Schmaus says in his preface that he learned of its American origin from merchants and sea-captains; but it is probable that this idea was first suggested by the use of guaiacum in this disease. Guaiacum came from America, and it was a common idea that the bane and the antidote belonged together and were to be found in the same vicinity. It is certain that the disease existed in America soon after the second voyage of Columbus.

After John de Vigo came Alexander Benedictus (145?–1525), who was professor of anatomy at Padua, an army surgeon, and who operated for hernia and calculus. He is the author of treatises on anatomy and on the pest, and of *De omnium a vertice ad plantam morborum signis, etc.* (Venice, 1535; Basil, 1594), which contains his surgical recommendations.

Jacobus Berengarius Carpensis (147?–1550), professor in Bologna, was the author of a celebrated treatise, *Tractatus de fractura calvariae seu cranei* (Bologna, 1518, quarto), of which a number of editions were published. This also contains a few remarks on the treatment of gunshot wounds, which he supposed to be burned or more or less poisoned. He acquired a great fortune at Rome by his treatment of syphilis with mercurial inunctions, of which he is reported to have been the inventor.

Alfonso Ferrius (1500–?) of Naples, the physician of Pope Paul III., wrote *De Sclopetorum sive Archibusorum Vulneribus, libri tres* (Rome, 1552, quarto), in which he maintains that gunshot wounds are poisoned and must be treated accordingly.

Bartholomæus Maggius (1516–62) of Bologna wrote *De Vulnerum Sclopetorum et bombardorum globulis illatorum, etc.* (Bologna, 1552, quarto), of which there were numerous later editions.

Leonardo Botallo (1530–?) wrote *De Curandis Vulneribus Sclopetorum* (Lyons, 1580, octavo), in which he opposed the views of De Vigo and Ferrius as to the poisoned condition of gunshot wounds.

Joh. F. Rota, who lived in the middle of the sixteenth century, wrote *De bellicorum tormentorum vulnerum natura et curatione liber* (Bologna, 1555, quarto).

One of the wisest of the Italian surgeons of this period appears to have been Michael Angelo Blondus (Biondi) (1497–15?) whose little

treatise *De partibus ictu sectis*, first published in 1542, and which is contained in the Gesner Collection and also in Uffenbach's Thesaurus, strongly urges the use of simple water and wetted lint in the dressing of wounds. Nevertheless, he was a partisan of the ancients, and two of his sayings have become historical as illustrating the university spirit of the age—viz. "It is more honorable to err with Galen and Avicenna than to acquire glory with others;" and, "It is better to die by a regular physician than to live by a quack."

One of the most celebrated Italian surgeons of the sixteenth century was Gaspar Tagliacozzi, better known as Tagliacotius (1546–99), who was professor of anatomy and surgery in the University of Bologna, and wrote the first special treatise on plastic surgery, and more particularly on the operation of rhinoplasty, with which his name is especially associated. The title of his book is *De Curtorum Chirurgia per insitionem libri duo*, of which two editions were published at Venice in 1597. One of these, a large folio published by Gaspar Bindonus, is celebrated for the beauty of its plates, the quality of the paper, and its typography, being a splendid specimen of book-making; the other edition of the same date and place, published by Robert Meiettus, is also a folio, but a much poorer specimen of the printer's and engraver's art. There is also a small octavo edition of Frankfort (1598), and one was published in Berlin so late as 1831. He does not name the person from whom he had learned his method, but it was probably from some one of the Incisori of his day who had acquired his knowledge from a pupil of one of the Sicilian Brancas, who were celebrated for operations of this kind in the middle of the fifteenth century. The elder Branca took his flaps for a new nose from the skin of the face, being the Indian method; his son made use of the skin of the arm, and extended the method to repair of mutilated lips and ears, as we are informed by Bartholomeo Fazia.

The first notice of Tagliacozzi's method is given by H. Mercurialis in his *De decoratione liber* (4°, Venet., 1585, fol. 23). Two of his pupils describe the methods and the results obtained, and acquired repute by their performance of the operation—viz. Thomas Fienus of Antwerp, and Jo. Bapt. Cortesius, who succeeded Tagliacozzi as professor at Bologna; but the practice fell into disuse among surgeons and little was heard of it until the beginning of the nineteenth century. A curious use of plastic surgery is mentioned by Fortunatus Licetus—viz. the making of double monsters for show purposes by grafting two boys together by the back, nates, or arms, upon which he says: "Averruncet Deus e severe puniant principes tales sicophantes." Victor Hugo refers to the work of these "monster-makers" in his *L'Homme qui rit*.

Marianus Sanctus Barolitanus (1490–154?), a native of Naples and a special pupil of John de Vigo, wrote a treatise entitled *Compendium in Chyrurgia Utilissimum Volentibus ipsas exercere*, which was first published at Rome in 1516, and subsequently appeared in connection with the works of De Vigo. It is also in the Gesner Collection of 1555. Neither Haller nor Malgaigne knew the date of the first edition, which is probably rare. The copy in the Washington Library is a small quarto of fifty leaves, unnumbered and unpaged, and is a fine specimen of black-letter printing. It contains three small rude figures of cauterizing irons, and the last nine pages are occupied with his *Tractatus de Capite*. Mari-

anus Sanctus is best known by his treatise *De Lapide ex vesica per incisionem extrahenda*, in which was, for the first time, published the method of John de Romanes for lithotomy with a grooved staff, upon which an incision was made into the membranous portion of the urethra, after which instruments were introduced to dilate or rupture the prostatic portion. This is known as "the method with the great apparatus," from the number of instruments required, and also as the "Marian operation," from the name of the person who first published the description. The first edition of this treatise appeared at Venice in 1535. It is contained in the Gesner Collection of 1555 and in Uffenbach's Thesaurus of 1610.

The "Gesner Collection," also known as the "Geneva Collection," is a beautifully printed folio with the title *Chirurgia. De chirurgia scriptores optimi quique veteres et recentiores, etc.* (Tiguri, 1555). It was edited by Conrad Gesner, and contains the principal surgical works of Tagaultius, Hollerius, Marianus Sanctus, Bologninus, Blondus, Maggius, Ferrius, Langius, and others, forming a valuable book of reference.

The first collections of the works of different writers on surgery were published at Venice, the first being a small volume issued in 1490, and again in 1497, containing the *Chirurgia parva* of Guy, the Surgery of Albucasis, and the commentary of Bertapaglia on Avicenna. A much more complete collection is the Venice folio of 1498, which contains the works of Guy de Chauliac, Brunus, Theodoricus, Lanfranc, Roger, and Bertapaglia. Of this the Venice editions of 1499 and 1519 are in the Washington Library; also the edition of 1546, which is the best and contains also the treatises of Roland and of William of Salicet.

From very early times there were to be found throughout Western Europe—in France, in Italy, in Germany, and in England—a certain number of surgical practitioners known to the writers of that time as "The Cutters" or "Incisors." Those who operated for lithotomy, hernia, etc. were of the first class. They travelled about from place to place, and maintained more or less secrecy as to their methods, which were held as a special family property, being handed down from father to son. Among these may be mentioned the two Brancas, to whom reference has been made in speaking of Tagliacozzi.

Another group of these travelling operators was known under the name of Norsini. These devoted themselves principally to operations for hernia and to lithotomy. Fabrice d'Aquapendente mentions Horace of Norsia as a skilled operator in hernia. Sylvaticus in 1601 complains that the operation of lithotomy was abandoned to ignorant persons, like the Norsini. In 1633, Cortesi writes that at Messina he had seen Ulysses of Norsia treat hernia by the application of caustic, followed by incision of the eschar; and still later, in 1672, Bernardino Genga says that the Norsini had some experience in the treatment of diseases of the urinary organs.

To this class of Cutters belongs probably the unknown surgeon mentioned by Senarega, who in his history of Genoa says that there died there in 1510 a surgeon very skilled in removing calculi. He introduced into the penis an iron rod, which entered the body until it met the stone which he was seeking, and which he then removed by a perineal incision. It is supposed by some that this unknown Genoese taught his method to John de Romanes of Cremona, who is ordinarily credited

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with the invention of the grooved staff for lithotomy, and who taug his method to his assistant, Marianus Sanctus.

The most famous of the Incisors was Pierre Franco, a native Provence, born about 1500, who operated in Provence, Burgundy, a Switzerland, finally settling in Lausanne for a considerable period, a in 1561 living at Orenge. His *Petit traité contenant une des part principalles de chirurgie laquelle les chirurgiens hernières exercent* w published at Lyons in 1556. In this he describes and figures t "Algalie" sound for detecting stone in the bladder; says that t calculus is sometimes encysted so that it cannot be felt by the soun describes the old operation of "cutting on the gripe," which he says formerly used; the operation with a grooved sound and gorget, of bo of which he gives figures, as also of forceps for crushing the stone if is large; and concludes that if the stone does not present itself when t incision is made, it is best to wait a day or two before attempting remove it. He describes a case in a child ten years old in which, bei unable to extract the stone through the perineal incision, he perform the suprapubic operation, removed the stone, which was the size of egg, and the patient recovered. This is the first recorded case of t high operation for stone. He says, however, that he does not adv this in ordinary cases. In his description of amputation he does n mention the ligature, but advises the actual cautery, and gives figures the sickle-shaped knife, the saw, and the cautery-iron. In 1561 he pu lished at Lyons his *Traité des hernies contenant une ample déclarati de toutes leurs espèces & autres excellentes parties de la chirurgie, assav de la pierre, des cataractes des yeux, & autres maladies, desquelles com la cure est perilleuse, aussi est elle de peu d'hommes bien exercée.* This a small octavo of 16 preliminary leaves, 554 pages, and 1 leaf of erra It contains all the matter of the preceding book, and much more, wi figures of new instruments, and is really a small manual of surge The part relating to lithotomy remains substantially the same. Next the works of Paré, this is the most valuable contribution of the centu to surgical literature.

The history of the Colot family is curious and interesting, but wrongly given by most of the biographers: the best is that given Dr. E. Turner in the *Gaz. Hebd. de Méd. et de Chir.* (Paris, 1880, xv 2e ser. pp. 33, 49).

The story that a certain Germain Colot, a French surgeon, learn the details of the methods of some of the Incisors about 1460, and the returning to Paris, operated on an archer who had been condemned to hung, but whose sentence was changed by the king to be operated on Colot, is probably without foundation. The original account, given the *Chronique scandaleuse*, does not mention the name of the operat and Malgaigne says that there is not even a presumption that there ev was a surgeon named Germain Colot.

There was, however, a Laurent Colot or Collot, who lived at Tresn near Troyes, in the middle of the sixteenth century, and who learn the method of John de Romanes—or what is called the Marian oper tion—from an itinerant lithotomist named Octavien da Villa. He ke the method a secret and had great success, being called to Paris in 155 and was appointed lithotomist of the Hôtel Dieu. The secret and t

office remained in the family, the grandson Philippe (1593–1656) being called to all parts of Europe to operate. His son François (1630–1706) wrote an account of the method, which was published after his death under the title *Traité de l'opération de la taille, etc.* (Paris, 1727). In it he refers to the above-mentioned story about Germain Colot, but does not give his name, and asserts that the operation performed on the archer was a nephrotomy and not a lithotomy. That the so-called family secret could have been preserved until the beginning of the eighteenth century, after the publication of the method by Marianus Sanctus in 1535 and by Franco in 1556, illustrates the education of the surgeons of those days.

We now come to an epoch-making surgeon, Ambrose Paré (1517–90), who was apprenticed to a provincial barber when he was about nine years old. In 1532 he came to Paris, where he was probably again apprenticed to a barber surgeon and attended the lectures of the doctor of the Faculty of Medicine of Paris, whose business it was to explain to the young barber surgeons those parts of the surgery of Guy de Chauliac which relate to tumors, wounds, and ulcers. Very soon after his arrival at Paris he had the good fortune to obtain a position as resident apprentice and dresser in the great hospital of the Hôtel Dieu. Here he had opportunities for dissections, for making post-mortem examinations, and for the study of disease, of which he was not slow to avail himself. In his preface to the reader he says: "You must know that for the space of three years I have lived in the Hôtel Dieu of Paris, where I had the means of seeing and knowing (in consequence of the great variety of diseases brought there) all which can be of alteration and disease in the human body, and to learn from an infinite number of dead all that can be said of anatomy."

At the end of this service, when he was but nineteen years old, he became body-surgeon to Mareschal Monte Jan, and went with him in the army which Francis I. opposed to that of Charles V. in the invasion of Provence in 1536. Gunshot wounds were supposed to be poisoned, and the recognized means of destroying the venom was that prescribed by John de Vigo—namely, cauterization by boiling oil. But in one battle the supply of oil was insufficient, and our conscientious youth could not sleep that night for thinking of the horrible fate that was in store for the poor fellows who had not been cauterized. Great was his astonishment and delight the next day on finding that those who had not been burnt were much more comfortable than those who had been treated *secundum artem*, and that recovery was prompter and more certain in their case. But, while Paré had the sense and the independence to refuse to give unnecessary pain, although commanded to do so by the highest surgical authority of his day, he could not free himself from the notion that some special treatment was required for gunshot wounds, nor accept the plain teaching of his own experience. He decided that the best thing to be done was to use a secret remedy which was the stock in trade of a certain surgeon in Turin, and to learn the composition of this remedy he assiduously courted the good graces of this surgeon for over two years and a half, and finally obtained the secret for a round price, promising not to divulge it. It was an oil of puppies, not much different from lard—a simple protecting soothing application. No sooner had Paré learned the secret than he hastened to publish it, deliberately breaking his promise

on the ground that such an important matter should not be one man's privilege.

The great improvement made by Paré in surgery was the use of the ligature to close bleeding arteries after amputation in place of searing them with red-hot irons, as had been done down to his time.

In the edition of his works published in 1564, *Dix livres de Chirurgie*, he first describes and recommends the application of a ligature to bleeding vessels in amputations, and abandons the use of the cautery. His account is as follows: After alluding to the passage in Galen which states that "the vessels must be tied toward their roots, which are the liver and the heart, to staunch the great flow of blood," he says: "But having many times used this means of closing the veins and arteries in recent wounds where there was a hemorrhage, I thought it might also be done in amputating a member. Therefore, having conferred with Estienne de la Rivière and François Rasse, both surgeons at Paris" [in later editions the name of Rasse is struck out and in place is read "other sworn surgeons of Paris"], "we agreed that we would make the trial upon the first patient which offered, although we would have the cauteries all ready to use if the ligature failed." A few days afterward the ligature was applied with success in a case of amputation of the leg.

Paré was a good anatomist, by far the greatest surgeon of his time, the confidential friend of four successive kings, and is said to have been the only Protestant in Paris who was spared the massacre of St. Bartholomew, which was due to the direct action of the king. Malgaigne's argument against the truth of this story cannot outweigh the direct statements of Sully and of Brantôme.

Catherine de Medici one day asked Paré whether he hoped to be saved in the next world. "Yes, certes, madame," said he, "because I do what I can to be a brave man in this world, and because the merciful God understands all languages, and is as well satisfied with a French prayer as with a Latin one."

To properly appreciate the writings of Paré, they should be compared with those of other teachers of, or writers on, surgery of his day. His treatise upon gunshot wounds may be compared with several small treatises on surgery published in the latter half of the century, thirty or forty years after the appearance of his treatise on this subject, and written in French for the benefit of the barber surgeons. Take, for example, the *Traitté des arcbusades* of Joubert, published at Lyons in 1574. Laurens Joubert (1529–83) was a distinguished physician of Montpellier, professor of medicine in the university and dean of the faculty. He had served in the royal army in the campaign of 1569, where he ought to have heard something of Paré's methods of treatment, but he makes no allusion to them, unless it be where he speaks of the oil of puppies as an anodyne. His *Surgery* is that of John de Vigo, written in a diffuse, pedantic style, which was probably impressive to the barbers in proportion to their inability to understand the meaning of his words. At one time he was called in as an umpire in an argument between a physician (Veyras) and the surgeon of the king of Navarre (Guilhemet) as to whether gunshot wounds are contused and should be treated by poultices, etc. or by desiccatives, as by washing with wine. The arguments on both sides and Joubert's decision were published in a curious little book

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entitled *Tracité de Chirurgie, contenant vraye méthode de guérir playes d'arquebusade, etc.*, par M. Jacques Veyras, docteur en Médecine, & M. Tannequin Guilhemet, Chirurgien du Roy de Navarre (Lyon, 1581, 8°). Joubert's decision was, upon the whole, in favor of the views of the physician, as was to be expected. He refers to Paré as "homme digne foy," not with reference to his treatment of wounds, but to his statement that bones may be fractured by the wind of a cannon-ball—this being precisely one of the points on which Paré was wrong.

The first teaching in French given to the barbers and surgeons was by a physician, Jean Canape of Lyons, physician of Francis I., who in the first half of the century gave public lectures to them, and for the same purpose translated into French a compend by Guy de Chauliac (Lyons, 1538, 12°; also 1563–71), some anatomical treatises of Galen (Lyons, 1541), and several other small treatises.

Pierre Tolet (1502–8?), a surgeon of Lyons, in 1540 published a translation into French of the sixth Book of Paulus Ægineta. In his prefatory letter to this, addressed to the French surgeons, he refers to Jean Canape as a man to whom surgery owes more than to any man who has written since Galen.

In 1570, Jacques Dalechamps, physician and reader in surgery at Lyons, published *Chirurgie Françoise* as a manual for the barber surgeons. It consists of the sixth book of Paul of Ægina, Hippocrates on fractures and dislocations, and extracts from Celsus, Albucasis, etc., with the annotations of Dalechamps, and a brief treatise on operations by Jean Girault, master surgeon in Paris.

In 1583, Esaie le Lievre, surgeon, published a little book entitled *Officinne et Jardin de Chirurgie militaire contenant les instrumentz et plantes tres necessaires a tous Chirurgiens, etc.* The general style of this work may be seen in the following sentence: "Nous disons l'harquebuzade ou playe faicte par harquebuze ou canom; estre une affection contre nature, portant de foy plusieurs especes d'accidens; a scavoir extreme contusion, combustion, diruption, dilaceratio, concution, fraction, fracation, puis repercution, abolitions, destructions, extinctions, ou mortifications, selon plus ou moings, des espritz tant vitaux, animaux, que naturels: de laquelle complication assemblee, selon la nature & noblesse des parties offensées, se forme une indisposition tendant a rendre ladite partie, consequement tout le subiect en cadaver."

The *Sclopetarius* of Quercetanus (Du Chesne) (Lyon, 1576) is a worthless book by a notorious charlatan. It was translated into English and published at London in 1590 by a certain John Hester, who offered for sale the Arcana prescribed therein. Care is taken to give two sets of remedies—one for the injuries of the common soldiers, the other "to be used for the rich." For advertising purposes the same John Hester published *A Short Discours of the excellent Doctour and Knight, maister Leonardo Phioravanti, Bolognese, uppon Chirurgerie* (London, 1580), advertising at the end that he is prepared to furnish various salves, philosophical oils, and other preparations recommended in it. Phioravanti explains that "the reason why white of egg is to be used in mixing applications for wounds is because the white is that part which produces the flesh, the skin, and the feathers of the hen, while the yolk engendereth only the intestines. Therefore the white is like

unto flesh, and its special business is to produce it." He says also that the most perfect remedy for a great flux of blood from a wound is to stitch it close, and then take dry human blood-powder and lay it upon the wound. This is the same as the mummy of Paracelsus.

The reference made by Paré as to the value of the instruction which he obtained in the Hôtel Dieu is perhaps the first allusion to the importance of hospitals as a means of furnishing instruction in surgery. Hospitals had existed since before the Christian era in India, and those in Persia under the Nestorians were really used for educational purposes in connection with their medical schools. The foundations of many European hospices and hospitals date from the tenth and twelfth centuries, such, for example, as the San Spirito at Rome and St. Bartholomew's and St. Thomas's in London, some of the impulse to the forming of such institutions apparently having come from the need of providing them for lepers.

No surgical instruction appears to have been given in the hospitals of the Middle Ages, except that the surgeons connected with them may have employed some of their apprentices to assist them in the bandaging and in the dressing of wounds; but what we know as "clinical surgery" was an affair of much later date.

Of the immediate pupils and followers of Paré, the most important were Pierre Pigray (1533–1613), whose published works are mainly abstracts and translations of Paré; and Jacques Guillemeau (1550–1612), surgeon of Charles IX., Henry III., and Henry IV., and surgeon of the Hôtel Dieu, who acquired fame as a writer and teacher in surgery, obstetrics, and ophthalmology. His *La chirurgie françoise* (Paris, 1594, folio) was translated into Dutch, and thence into English, and published at Dort in 1597 under the title of *The French Chirurgerye*, forming a beautifully printed and illustrated folio, which was much the best work on this subject which had then appeared in English. Guillemeau was unusually well educated for a surgeon of those days, having studied under Riolan as well as under Paré, and he tried to harmonize the statements of the latter and those of his opponent, Gourmelin, by saying that Galen recommends the cautery in amputation for gangrene, and approves the use of the ligature for hemorrhage when there is no corruption.

Paré in advising the application of the ligature says it does not matter if some other tissue besides the vessel is included in it; but Guillemeau says that a portion of such tissue is to be included: "prenant quelque portion de chair ensemble," evidently thinking that this is an important feature of the operation.

His chapter on aneurism contains an account of a case of traumatic aneurism at the bend of the elbow in which he applied a single ligature above the swelling with success. In this case the aneurism had ruptured, and after ligating the artery he opened it further and turned out the clots. This one ligature was placed three fingers'-breadth above the tumor. Paré's description of the operation also refers to the use of but one ligature, and not to the operation of Antyllus.

There were no surgeons of repute in Germany prior to the middle of the fifteenth century; they were almost all barbers, who could neither read nor write. In 1868 there was for the first time published a manuscript treatise on surgery written in German about 1460

by Heinrich Pfolzprundt, and entitled *Bundth-Ertznei*. This, the oldest German work on surgery at present known, relates mainly to the treatment of wounds, but it contains a remarkable chapter on the making of a new nose from the skin of the arm after the method of Branca. There is an allusion to the burning of wounds by powder, but no reference is made to lithotomy or to operations for hernia. It gives a receipt for a narcotic mixture to be inhaled from a sponge similar to that mentioned by Guy de Chauliac. The first German surgeons of repute whose works have come down to us are Hieronymus Brunschwig, and Hans von Gersdorff, called Schylhans or Schielhans, both being surgeons at Strasburg in the last half of the fifteenth century. Brunschwig was born about the middle of the fifteenth century, and published at Strasburg in 1497 a folio volume with the title *Dis ist das buch der Cirurgia, Hautwirck der Wundartzny von Hyeronimo brunschwig*. Of this there were eight other editions, the last at Augsburg (1539, quarto). The Washington Library has the folio editions of 1508 and 1513 and the quarto editions of 1533 and 1539; also the English translation of 1525, and a Dutch translation in folio printed at Utrecht in 1535. The English translation is the first book on surgery in English, and its title-page is a curiosity in itself. It begins as follows:

"The noble experyence of the vertuous handywarke of surgeri practysyd & compyled by the moost experte Mayster Jherome of Bruynswyke borne in Straesborowe in Almayne ye whiche hath it fyrst proved and trewly founde by his awne dayly exercysynge."

This title is the work of the unknown translator, who has also given a short preface, in which he says that "it is oftentymes sene and dayly chaunceth in small townes, borowghs and villages that dyverse people hurt or dyseased for lacke of connynge men be taken in hande of them that be barbers or yonge maisters to whome this sciens was never dysclosed, not thynkynge on the wordes of the olde lernyd men that say, It is not wel possible to man that he sholde brynge well to a good end the thynge whiche he never or hath but lytell seen."

Brunschwig's book was the first in which any definite statement is made about gunshot wounds, or, as the English translation has it, "of woundis shot with a gone whereas the venym of the powder abydyth in." To remove the venom he advises to pass a small cord of hair through the wound and draw it back and forth, after which a tent is to be placed in the wound.

In amputation he advises either the actual cautery or boiling oil to check hemorrhage. He has nothing to say about lithotomy, herniotomy, aneurism, or tumors—the book being, in fact, a treatise on the military surgery of those days. It is illustrated with large quaint wood-cuts which are among the earliest specimens of the art. Haeser says there were two English translations—one published at London, and the other at Southwark, but these are the same work.

Hans von Gersdorff was an army surgeon in 1476–77, and published his book, *Feldtbuch der Wundtarzney* (in folio), at Strasburg in 1517. Of this there were eight later editions and translations into Latin and Dutch. The Washington Library contains the first edition, and also the Strasburg editions of 1527 and 1540 and the Frankfort edition of 1551. Gersdorff treats more fully of shot-wounds than does Brunschwig.

He does not consider them to be poisonous, but gives detailed directions for finding and extracting the bullet, with figures of instruments, and advises that the powder be removed, after which warm linseed oil is to be poured into the wound. He says: "I do not know of any better or milder remedy than this, which I have learned from Master Nicolaus, called the Maulartzt, surgeon to Duke Sigmund of Austria." If amputation becomes necessary, he says: "First of all advise the patient to resign himself to God, to confess his sins, to remember the suffering of our Lord with thanks, and the surgeon the same; thus will God grant him good fortune in his work. And when you will cut him have ready by each other all your instruments and apparatus, such as scissors, knife, saw, styptics, bands (lassbendel), bandages, pads, tow, eggs, and what belongs to it, so that one follows the other in the order of the operation, since there is need of this. And when you are ready to cut let some one draw back the skin strongly and tie a band firmly around it, and place another band in front so that a space of a finger-breadth be left between the two bands that you may cut between them with the knife; then this cut is quite sure, easily made and makes a good stump. When you have made the cut take a saw and divide the bone, and then remove the band and tell some one to draw the skin over the bone and flesh and hold it tight in front; and you should have a bandage two fingers broad and well wetted that it may lie smooth, and with it bandage the thigh down to the cut that the flesh may go in front of the bone, and leave it thus bound. And you need not fear bleeding if you have done as above described. Bind now over the styptic a good thick pad, take the bladder of a bull, ox, or hog, one which is strong, cut the neck open so that it will go over the pad and stump, and the bladder should be wet but not too soft; draw it then over all, tie it hard with a band and you need have no care about the bleeding."

The following is the styptic referred to: "Take of unslacked lime two ounces, vitriol, alum, each, one ounce, of aloes to be calcined, gall-nuts, colophony each a quarter of an ounce; of the residuum in the retort when you make aquafortis two and a half ounces, and the white hair of the belly of a hare or deer chopped up, and mix all together thoroughly. When you use it mix it with white of eggs. . . . . But if an artery rages and will not be staunched then burn it with a cautery." Although he used no ligature in amputation, he does advise a double ligature on a wounded blood-vessel. He has a chapter on leprosy, but says nothing definite about syphilis. The plates in Gersdorff's book are especially interesting.

Walter Hermann Ryff was also a Strasburg surgeon of the first part of the sixteenth century, and published a number of treatises in German, his *Gross Chirurgei* appearing in 1545, and his *Kleiner Chirurgi* in 1551. This tendency to depart from scholastic methods received a strong impulse from the sayings, doings, and writings of Philippe Aureole Theophrastus Bombastes de Hohenheim, better known as Paracelsus (1493–1541). He was born in the village of Einsiedeln, near Zurich, studied medicine with his father, travelled extensively, studied chemistry and alchemy with Sigismund Fugger, and served as an army surgeon in campaigns in Italy and the Netherlands. Of unbounded self-assurance and having a knowledge of some new reme-

dies, such as antimony, arsenic, and mercury, he soon acquired a great reputation, and in 1526 was appointed professor of medicine in the University of Basle. He is characterized by Dalton as "a rampant, blatant, boasting, ignorant vagabond, with a face of brass and a tongue like a race-horse," and, if the word "ignorant" be omitted, it is a true picture. But he was also a sort of genius, in a way a poet; and, knave and charlatan, and in his latter days drunkard, though he was, his doctrines were accepted by such men as Frobenius, Erasmus, and Van Helmont, and had a powerful influence throughout Europe for a century or more, some of his peculiar theories still surviving as the essence of modern homœopathy. He wrote or dictated many works, of which the only one that need be mentioned here is *Der grossen Wundartzney* (1536–37), of which there were several editions, besides Latin and French translations. The second chapter begins as follows: "It is necessary to know in the first place what is the efficient cause of the curing of wounds, because this may of itself indicate the proper treatment. Know then that the human body contains in itself its own proper radical balsam, born in it, and with it, and not only the body as a whole contains it, but all its parts, such as flesh, bones and nerves, have each its own peculiar juice competent to cure wounds. . . . . It is not the surgeon who cures wounds, it is the natural balsam (or juice) in the part itself." Hence he inveighs against what he calls "the damnable precept which teaches that it is necessary to make wounds suppurate." Elsewhere he calls this animal juice "la mumie," but he also meant by this a special preparation made from certain parts of the human body—something like the animal juices and extracts which have been recently recommended as remedies, and which are quite Paracelsian in character.

The ideas of Paracelsus were accepted by Felix Wurtz (1514–74) of Basle, who studied under Ryff at Nuremberg, and was on terms of intimacy with Paracelsus and with Conrad Gesner, the most learned man of his time. He acquired great reputation, and published his *Practica der Wundarzney* in 1563. Of this about fifteen editions appeared during the next hundred years, including an English translation by Fox, published in 1656. He remarks that "skill in surgery is obtained with great painfulness, for it is not gotten with sitting on a cushion at home and by reading and writing; . . . . it is not enough to be full of talk, and to say such and such and write so and so,—a patient is little the better for it if the surgeon hath no skill to dress his wounds." The work is almost entirely devoted to wounds and fractures and their consequences, and contains nothing as to the technique of surgical operations. The treatment advocated is in the main simple and sensible. Styptic powders are condemned for general use, as is also the cautery to suppress hemorrhage, except in amputation of the thigh. No allusion is made to the ligature, and it is not probable that he had ever seen the works of Paré. He objects to the probing of wounds, declaring that it is folly to feel and grope about them, and that some surgeons use the probe merely because they have seen it used and to show that they are doing something. Cataplasms and poultices for fresh wounds are condemned, and the blood is not to be washed or squeezed out, "for it is a right flesh glue and hasteneth the healing." He often refers to the conservative surgeons

who say, "Old customs should not be abandoned," and says, "Therefore in some places the books of Theophrastus Paracelsus (to whom the best and most famous surgeons must give place) are prohibited to be read; but in my simple judgment it is done very foolishly." He objects to drawing a cord through a gunshot wound, or to using hot oil, or to treating such injuries otherwise than as simple wounds. The third part of his book, being on the symptoms and complications of wounds, including a description of the wound-fever or pyæmia, is the most original and valuable part of the work.

The instruction of the barber surgeons' apprentices at the end of the sixteenth century appears to have been based on the views of Jerome of Brunswick, if we may judge from a little manual by Julius Holder, published at Frankfort in 1592, entitled *Dialogus, ein Nützliche und Warhafftige Beschreibung eines rechte Wundartzts unnd seiner Meisterschaft.* This is in the form of questions and answers, Latin terms being curiously intermixed with the German.

Another good specimen of the sort of instruction given to apprentices of German barber surgeons in the sixteenth century is the *Wundartzney zu allen gebrechen des gantzen Leibs, etc.* of Joannes Charethanus (or Charetanus), of which five editions appeared between 1530 and 1556. The edition of 1549, printed at Frankfort, is a small quarto of 20 leaves, giving directions for bloodletting and tooth-pulling, and various formulæ for salves and potions. It directs that wounds should be dressed twice a day; that he who is wounded in the head shall not walk about or move much; that he shall avoid perspiring and talking, which inflame or disturb the brain and make him insensible; above all, he shall avoid strong wine, which puts him in deadly peril; likewise the rays of the sun and light and heat and indigestible meat and the society of woman, whom he shall not even look upon.

If a large artery is cut or opened, first secure the same carefully with a silk thread to stop the bleeding; then lay on the red powder and cover with a red plaster. Let it remain for four days and heal it like other wounds.

The Seventeenth Century.

The seventeenth century is more remarkable for the advances which were made in physics and in physiology than it is for improvements in surgery. It was the age of Francis Bacon (1561–1626), of Galileo (1564–1642), of René Descartes (1596–1650), of Pascal (1623–62), of Sir Isaac Newton (1642–1727), and of Robert Boyle (1626–91), all of whom had a powerful influence in developing the iatro-chemical and iatro-mechanical theories which prevailed about the end of the century. This was also the age of Borelli (1608–79), of Thomas Sydenham (1624–89), and, above all, of William Harvey (1578–1657), the pupil of Fabricius d'Aquapendente, whose celebrated work, *Exercitatio Anatomica de Motu Cordis et Sanguinis*, appeared in 1628.

At the commencement of this century the most distinguished Italian surgeon was Hieronymus Fabricius d'Aquapendente (1537–1619), who was a pupil of Fallopius and succeeded him as professor of anatomy at Padua. He was the discoverer of the valves of the veins and the teacher of Harvey. His principal discoveries and writings relate to anatomy

and embryology, but he was also professor of surgery, and his *Pentateuchos Chirurgicum* (Francof., 1582) and his *Opera Chirurgica* (Paris, 1613, in folio, and later editions) were important works of reference during the next century. Fabricius was learned and eloquent, and made the University of Padua the most important school for anatomy and surgery in Europe. His surgery is mainly that of Celsus, Paul of Ægina, and Albucasis, to whom he gives full credit, carefully noting the sources of his quotations. No great advance in the art is due to him, but his works contain many accounts of cases and references to the methods of other surgeons, making them valuable historically, and they are far more interesting as a piece of literature than is the corresponding work of John de Vigo. In speaking of wounds of the intestines he refers to animal sutures and to the insertion of a piece of the trachea of an animal to preserve the lumen of the gut. He describes tracheotomy and urges its performance in certain cases, and says that he has seen one case of cancer of the breast cured by excision, but has never performed the operation himself.

Next to him came Cesare Magati (1579–1647), who became professor at Ferrara in 1612 (or 1621?), and who gained much repute by his book, *De rara medicatione vulnerum, seu de vulneribus raro tractandis* (libri ii., Venet., 1616, folio). In this he urged a simpler mode of treating wounds than was then fashionable, advising less frequent dressings, condemning the use of tents, and maintaining that gunshot wounds are not poisoned. His doctrines were specially urged and made prominent by Sancassini in the early part of the eighteenth century.

Marcus Aurelius Severinus (1580–1656), professor at Naples, one of the most celebrated teachers of anatomy and surgery of his time, is best known by his book *De recondita abscessuum natura* (Naples, 1632, quarto), of which several later editions were published.

Giovanni Battista Cortesi (1554–1636), a barber's apprentice, afterward a pupil of Tagliacozzi, whom he succeeded as professor at Bologna, published a treatise on wounds of the head in 1632, and a manual of surgery in 1633, which are of little interest.

Gaspar Asellius, the discoverer of the lacteals, in 1623 was professor of surgery and anatomy at Pavia, but wrote nothing on surgery.

Spigelius (1578–1625), a native of Brussels, professor of anatomy and surgery at Padua in 1605, was an operator, and is said to have trephined the same patient seven times, but there is nothing surgical in his published works. Trephining was a common operation at this time, being employed in cases of insanity, of severe headache, and of chronic diseases of the eyes, as well as for injuries of the skull.

Pietro de Marchetti (1589–1673), professor of surgery at Padua, published a collection of cases under the title *Observationum medico-chirurgicarum sylloge* (Padua, 1664, and later editions), which is of permanent historical value. Among these cases is one of successful trephining following a dagger-wound of the head two or three months previous, and several cases of the same operation for headache. Here also is the celebrated case in which a pig's tail was forced into the anus of a prostitute, and was removed by slipping a tube over it. Pietro was succeeded in the chair of surgery in 1662 by his son Dominique, who acquired great fame as a teacher, and is said to have performed nephrot-

omy successfully without being guided by the presence of any tumefaction of the part.

Filippo Masiero, a surgeon of Padua, was the author of the following books: *Il chirurgo in prattica, etc.* (Venet., 1688, 4to; 5th ed 1749, 8°), *Il sogno chirurgico* (Parts I., II., Padua, 1697), and *Oper chirurgische* (Padua, 1707).

Carolus Musitanus, a physician of Naples, published his *Chirurgi theoretica practica* in 1698. Haller styles him "improbabilium historiarum narrator."

In France there was little progress in surgery until near the end of the century. The medical faculty finally triumphed over the surgeon by obtaining a decree which united the barbers and the surgeons in on corporation, and the College of St. Côme was no longer a power in th land. Among the French works on surgery of this period may be mentioned *Quelques traités des opérations de chirurgie*, by Jean Girault (Paris 1610); *Observations Médecinales et Chirurgicales, etc.*, of Gul. Loyseau (Bordeaux, 1617); *Observations iatrochirurgiques* of Covillard (Lyon 1639) and *Le Chirurgien Opérateur* of the same author (1633 ?; 2d ed. Lyon, 1640); *Epistola de laryngotomia* of René Moreau (Paris 1646); *La Chirurgie Militaire* of Leonard Tassin (Nimwegen, 1673) *Les opérations de la chirurgie* of J. Bienaise (Paris, 1688); and *Trait des playes d'arquebusade* of Scipio Abeille (Paris, 1695).

In 1696, M. de la Vauguion, a physician, published a *Traité compl des opérations de chirurgie* (8°, Paris), which is the most complete manual in French prior to that of Dionis, and of the English translation of which at least three editions were published (1699, 1707, and 1716). H names the tourniquet and describes its application in amputation an in the operation for aneurism, and quotes frequently from Fabricius Hildanus.

Nicolas de Blegny (1652–1722), surgeon of the duke of Orleans i 1683, the founder of the first medical journal, published a treatise o venereal diseases in 1673, and a treatise on the treatment of hernia, wit description of a truss of his invention, in 1676. He is also the autho of the first city directory.

Previous to the seventeenth century surgery had made little progress i the Netherlands, and there are very few books to be noted. The work o Ypermans has already been referred to. Carolus Battus, a surgeon of Dor drecht, published in 1590 his *Handtboeck der Chirurgijen*, of which ther were six later editions. He also translated the works of Paré into Dutch

In the middle of this century Holland became celebrated as a centr of anatomical and surgical teaching through the labors of Tulp, Bar bette, Van Meekren, Van Horne, Van Roonhuysen, Solingen, Verduyn and others, and the schools of Amsterdam and Leyden began to dra students from all parts of Europe.

Paul Barbette (162?–7?), son of a Strasburg surgeon, studied i Montpellier and Paris and settled in Amsterdam. He was a voluminou writer, and his *Chirurgia*, first published in Dutch in 1657, passed throug ten editions and translations, being a popular manual, while his *Oper omnia* was issued twenty-two times in various languages. He firs described femoral hernia, suggested laparotomy in intestinal obstruction, and extirpation of the spleen, which he performed on dogs.

Job Janszoon Van Meekren (?–1666), a native of Amsterdam and a pupil of Tulp, was a celebrated operator. His book, *Heel en geneeskonstige aanmerkingen* (Amst., 1668), was translated into German and Latin.

Joh. van Horne (1621–70), professor of anatomy and surgery in Leyden, was a distinguished teacher, but his writings relate mainly to anatomy, his *Microtechne id est brevissima Chirurgiae Methodus* (1663) being merely a manual. There is an English translation of this (London, 1717).

Hendrik van Roonhuysen (1625–6?), a surgeon of Amsterdam, also well known as an obstetrician, published his *Genees-en Heelkonstige aanmerkingen* in 1672. He operated for wry-neck and hare-lip, advised Cæsarean section, removed tumors, and seems to have been specially skilled in his art.

Cornelis Solingen (1641–87), a surgeon at the Hague, wrote *Manuale Operatien der Chirurgie* (Amst., 1684), which Haller says is full of original observations.

Peter A. Verduyn (162?–?), a surgeon of Amsterdam, is celebrated for his treatise on the flap method of amputation, *Diss. de nova artuum decurtandorum ratione* (Amst., 1696). He seems to have known nothing of the similar methods of Lowdham. (See p. 67.)

Joannes Muys of Arnhem and Leyden published the first two parts of his *Praxis Chirurgiae rationalis* in 1683, and the complete work in 1695. This contains accounts of one hundred and twenty cases, some of which are curious and interesting.

Fabricius Hildanus (1560–1624) is sometimes called the "Father of German Surgery," although this title belongs more properly to Heister. He was a Swiss by birth, and for the last twenty years of his life was the city physician of Berne. He was a surgeon's apprentice who managed to acquire a good classical education, and probably obtained good practical training under Griffon, a surgeon of Geneva. He travelled much, resided for some time at Cologne, and became widely known as a bold and skilful operator, and especially as a lithotomist. He was a strong opponent of Paracelsus and his friend Wurtz, and was a voluminous writer, but his monographs are, for the most part, of little interest, the best being his *Lithotomia Vesicae* (Basle, 1626), translated into English and published at London in 1640. His most important publication for readers of the present day is his *Observationum et Curationum Chirurgicarum Centuriae*, in which he relates his experience in a large number of surgical cases of the most varied character. He advised amputation at an early stage in gangrene, and that the incision should be made in the sound and not in the decayed flesh.

He used the cautery, and not the ligature, in wounds of the arteries, and devised a number of complicated instruments, none of which are of practical interest. His chief influence on surgery was through his correspondence with German physicians and surgeons, and through his urging upon the German surgeons the necessity for the study of anatomy. His *Opera omnia*, of which several editions were published, appears to have been a favorite book of reference for surgeons for many years.

John Schultes, better known as "Scultetus" (1595–1645), a pupil of

Fabricius d'Aquapendente, became city physician at Ulm. His great work, the *Armamentarium Chirurgicum* (Ulm, 1653, folio), passed through many editions and was translated into many languages.

Joseph Schmidt (1601–?), an army surgeon, published *Speculum Chirurgicum* (Ulm, 1656, quarto) and *Examen Chirurgicum* (Francof. 1660, 16°).

The most celebrated German surgeon of the latter part of this period was Matthæus Gottfried Purmann (1649–1711 ?), who was apprentice as a barber surgeon, became a medical officer in the Brandenburg army in 1675, and city physician at Breslau in 1685. He was a voluminous writer, and his *Grosser und gantz neu-gewundener Lorbeer-Krantz, oder Wünd-Artzney* (Francof., 1692, 4to; also 1722), his *Chirurgia Curiosa* (Francof., 1694, 4to; translated into English, London, 1706, fol.), and his *Funffzig sonder- und wunderbahre Schusswunden Curen* (Francof. 1721) are valuable works in the history of the art. He was a strong advocate of the cure by the weapon-salve and the sympathetic powder, and tells several stories of the successful use of these remedies. He uses styptics and bandages to control hemorrhages after amputations, objecting to the cautery, but says nothing about the ligature.

Here may also be mentioned John von Muralt (1645–1733), a distinguished Swiss anatomist and surgeon, who was one of a celebrated family of physicians of Zurich. He studied at Basle, Leyden, Oxford and Paris, and in 1761 returned to Zurich, where he soon became distinguished as an anatomist and surgeon. In 1677 he announced public lessons in anatomy, with demonstrations on the bodies of criminals and of persons dying of remarkable diseases in the hospitals, and in the same year published his *Vade Mecum Anatomicum*, giving the date by the enlarged letters in the motto of the book, "LVX et faX MeDICInæ." In the second edition of his surgical writings, published in 1711, he describes a method of amputation by flap devised by Saborian in Geneva, who first performed it in 1701, and this is by some claimed to be the first mention of that method of operation, but it had already been described by Yonge in 1679. (See p. 67.)

Other German surgeons of this period were Mathias Ludwig Glandorp (1595–1636), whose *Speculum Chirurgicum* appeared in 1619; Jesseniu a Jessen (1566–1621), author of *Institutiones Chirurgicae* (1601); Paul Ammann (1634–91), author of *Praxis vulnerum lethalium* (Francof. 1690); Joh. Agricola (1589–164?), author of *Chirurgia parva* (Nürnberg, 1643); and John H. Jungken (1648–1726), author of *Compendium Chirurgicae Manualis absolutum* (Francof., 1692).

The oldest English medical book which we have is perhaps the *Leech book*, written about 970 A. D., and printed in 1865 as volume ii. of the *Leechdoms, Wortcunning, and Starcraft of Early England*. This is mainly the receipt-book of a herbalist, giving the uses of common herbs, and among other things the composition of various "wound-salves." But it also contains matters taken from Paul of Ægina, and directs: "If thou must carve off or cut off an unhealthy limb off from a healthy body, then carve thou not it on the limit of the healthy body, but much more cut or carve in the hole and quick body." The following is the best surgery in the book: "For hare-lip, pound mastic very small, add the white of an egg, and mingle as thou dost vermillion; cut with a knife the fals

edges of the lip, sew fast with silk, then smear without and within with the salve, ere the silk rot. If it draw together, arrange it with the hand; anoint again soon."

In the book of *The Physicians of Myddvai*, which dates from about the thirteenth century, there are a few references to surgical operations. The author says (page 40): "A wounded lung is the physician's third difficulty, for he cannot control it; but he must wait for the will of God. By means of herbs a medicine may be prepared for any one who has a pulmonary abscess [empyema]. He should let out [the matter] and support [the patient] as in the case of a wounded lung, till he is recovered. But most usually he will have died within eleven years [or one year]." Page 44: "A hard vesical calculus is thus extracted by operation: Take a staff and place it in the bend of the knee; then fix both arms within the knees, doubling them over the staff, and securing both wrists with a fillet over the nape of the neck, the patient (being placed on the back), his stomach up, with some support under both thighs, and the calculus cut for on the left side of the urethra. Let him subsequently be put in a water-bath that same day, also the day following early, and after this he should be put in the kyffeith. Then he should be removed to his bed, and laid there on his back, his wound being cleaned and dressed with flax and salt butter. He should be kept in the same temperature until it be known whether he shall escape [effects of the operation]. He should be kept without food or drink for a day and a night previous to the operation, and should have a bath."

The following is the direction for an anæsthetic (page 423): "Take the juice of orpine, eringo, poppy, mandrake, ground-ivy, hemlock, and lettuce, of each equal parts. Let clean earth be mixed with them and a potion prepared, then without doubt the patient will sleep. When you are prepared to operate upon the patient, direct that he shall avoid sleep as long as he can, and then let some of the potion be poured into his nostrils, and he will sleep without fail.

"When you wish to awake him, let a sponge be pounded in vinegar and put in his nostrils.

"If you wish that he should not wake for four days, get a pennyweight of the wax from a dog's ear, and the same quantity of pitch; administer it to the patient and he will sleep.

"When you would that he should awake, take an onion, compounded with vinegar, and pour some into his mouth, and he will awake. Take care that you keep him quiet, and warned of the operation, lest he should be disturbed."

The first surgeon in England of whom we have any definite account, and whose writings still exist, was John of Arderne (or Arden), born about 1308, who practised in Newark until about 1370, when he went to London. He wrote a treatise on surgery of which several manuscript copies are in existence, but the only work of his which has been printed is *A treatise of the fistula in the fundament, or other places of the body, etc.*, which is included with the translation of Arcæus on wounds of the head, etc., printed in London in 1588, being a translation by John Read. His operation itself consisted either of slitting up the fistula or of passing a thread through it, which is to be drawn so as to cut through the flesh gradually.

His description of cancer of the rectum is a graphic one, and begin as follows:

"Bubo is an Apostume breding within the fundament in the longa tion with great hardness, but with little paine. This before his ulcera tion is nothing but a hid Cancer, which cannot in the beginning b knowne by sight of the eye, for it is hid within the fundament, an therefore it is called Bubo. For as an Owle hideth her self in the dark places, so this griefe lurketh within in the beginning.

"But after processe of time it is ulcerat and frettith and goeth ou and oftentimes it frettith and ulcerith all the circumference of the funda ment, so that the excrements goeth out continuallie without retencio and may never be staied unto the death, nor cured by the healpe of man And it is thus knowen.

"Put your finger within the fundament of the pacient, and if y finde within a thinge very harde, sometime on the one side, and sometim on both, which hindreth egestion, than it is Bubo.

"And the manifest signs are these. The patient cannot abstaine fro stoole, for aking and priking, and that twise or thrise within an hour and the excrementes seeme as it were mingled with watrie bloud, and stinketh very strongly, so that all the unskilfull surgions and the patien also thinketh they have Dissenterium, when truely it is nothing so, fo Dissenterium is with flux of the belly, but in Bubo there goeth foort hard egestion and sometime they may not goe out for straightnesse o the Bubo, but are reteyned within the fundament straightly so that y may feele them with your finger and drawe them out, and in this cas glisters availeth much.

"And when they bee nigh their ende, they beginne to have lynge ing fevers, and to loose their appetite, they forsake all, and covet win they eate little and covet everieday lesse and lesse, they sleepe but litt and unquietly, they are heavie as well in minde as in body, and as the waxe weaker and weaker, they covet their bedde and above all thinges t drinke water, neverthelesse they can speake and move themselves to th last breath.

"From these (I say) wash your handes if you have care of your credi unlesse it be in glisters as aforesaide to ease him."

At the beginning of the fifteenth century there was a great dearth o surgeons in England, as it appears from Rymer's *Fœdera* that in 141 Henry authorized "John Morstede to press as many surgeons as h thought necessary for the French expedition, together with persons t make their instruments.[1] With the army which won the day at Agin court there had landed only one surgeon, the same John Morstede, wh indeed did engage to find fifteen more for the army, three of whom wer to act as archers."

Of the English surgeons of the fifteenth and sixteenth centuries, tho whose names are best known are Vicary, Gale, Clowes, and Low Thomas Vicary (149?–1561), the first master of the Amalgamated Ba bers and Surgeons in 1541, and one of the first governors of St. Ba tholomew's, published in 1548 a work on anatomy in English. No cop of this edition is known to exist, but the edition of 1577 was reprinte by the Early English Text Society in 1888. Thomas Gale (1507–86),

[1] *The Antiquary's Portfolio*, by J. S. Forsyth, vol. i., London, 1835, p. 80.

native of London, served in the army of Henry VIII. in France in 1544, and under Philip II. of Spain in 1577, succeeded Vicary as master of the Barber Surgeons Company in 1561, and in 1563 published his *Institution of Chirurgerie*, with other treatises, one of which is *Of wounds made with Gonneshot*, in which he opposes the views of Brunswick, De Vigo, and Ferrius as to the venomous nature of such wounds, and quotes Maggius approvingly. He advises styptics in amputations—says that his method is used in St. Thomas's Hospital, and gives cases to prove that bullets may be left in the body without danger.

William Clowes (1540–1624) was at first a naval surgeon, and became surgeon of St. Bartholomew's in 1581. He wrote *A proved practise for all young Chirurgions concerning burnings with Gunpowder and Woundes made with Gunshot, etc.* (London, 1591, 8°; 3d ed. 1637, 4°). He refers to Paré as a man worthy of admiration, and, like Gale, comments severely on the ignorance of the so-called surgeons of his time. Peter Lowe (155?–161?), a Scotch surgeon, practised for a long time in France and Flanders and as an army surgeon. In 1596 he was in London, where he published his works on the *Spanish Sickness* and *The Whole Course of Chirurgerie*. In 1598 he returned to Glasgow, and founded the Faculty of Physicians and Surgeons of Glasgow, which was chartered by King James VI. in 1599. His book on surgery passed through four editions, and is a good manual for its time. In amputation for gangrene he used the actual cautery, but says: "In amputation without putrefaction I finde the ligature reasonable sure providing it be quickly done." This is perhaps the first mention in English of the ligation of arteries in amputation. In hernia he advised the pricking of the intestines with a needle to discharge the wind and lessen the bulk of the tumor.

About the middle of the sixteenth century there lived at Maidstone, Kent, a surgeon named John Halle, who published in 1565 a translation of the *Chirurgia parva* of Lanfranc, with some remarks of his own, entitled *An Historical Expostulation also against the beastly abusers, both of Chyrurgerie and Physicke in our tyme: With a goodly doctrine, and instructions necessary to be marked and followed of all true Chirurgies.*

The history of surgical corporations in England begins with the barbers' guild, which was at first a meeting for social and religious purposes, originating probably in the thirteenth century. These barbers soon began to call themselves barber surgeons. There were, however, surgeons who were not barbers, some of whom had served in the army, and in 1368 these surgeons formed a separate guild, which about 1421 combined with the physicians.[1] The barbers obtained a charter of incorporation from King Edward IV. in 1462.

There is nothing in the charter about barbery—that is, shaving and hair-cutting—but a good deal about the regulation of surgery. In 1492 arms were granted to the "Guild of Surgeons," which appears to have been a small body of eight or ten men superior in social position to the

[1] The details of the quarrels between the barbers and the surgeons, and of the organization and progress of the guilds, will be found in *The Annals of the Barber Surgeons of London*, compiled by Sidney Young (a thick quarto volume published in 1890), and in *The Craft of Surgery*, by J. Flint South (published in 1886). The act of Parliament passed in 1540, allowing the United Companies of Barbers and Surgeons to have yearly four bodies of criminals, was the first law in the country for promoting the study of anatomy.

barbers. In 1540, under the reign of Henry VIII., the barbers a the surgeons were united and incorporated by act of Parliament as t Company of the Barber Surgeons, the first master being Thomas Vica

In the year 1542 an act was passed regulating the practice of surge stating that "the Company and Fellowship of Surgeons of Londo minding their owne lucres, and nothing the profit or ease of the disea or patient, have sued, troubled, and vexed divers honest persons, as w men as women, whom God hath endueed with the knowledge of t nature, kind and operation of certain herbs, roots and waters, and t using and ministering of them, to such as have been pained with custu able diseases, as women's breasts being sore, a pin and the web in the e uncomes of the hands, scaldings, burnings, sore mouths, the stone, stra guary, saucelin, and morphew, and such other like diseases. . . . . A yet the said persons have not taken anything for their pains or cunnin . . . . In consideration whereof, and for the ease, comfort, succour, hel relief, and health of the King's poor subjects, inhabitants of this h realm, now pained or diseased, Be it ordained, etc. that at all time fro henceforth it shall be lawful to every person being the King's subje having knowledge and experience of the nature of herbs, roots a waters, etc., to use and minister according to their cunning, experie and knowledge, ... the aforesaid statute . . . . or any other A notwithstanding."

The Barber Surgeons had public demonstrations of anatomy and di sections in their hall, but it was forbidden that any of them should ma dissections or give lectures on anatomy at any place other than said ha The reader in anatomy was for many years a physician.

In 1604 the company was presented with five hundred copies of t *Tables of Surgery* of Horatius Morus, a Florentine physician, translat by Richard Caldwell[1] (London, 1585, 32 pp. 8°). These books we given by Mr. Caldwell to be distributed among the surgeons who we freemen of the company.

In 1643, Edward Arris gave to the corporation the sum of two hu dred and fifty pounds for the purpose of having one human body pu licly dissected and six lectures thereupon read each year.

The Gale Lectureship was founded by Dr. Gale, the order being issue in 1698. These two bequests are now combined and the lectures in co nection with them are known as the Arris and Gale Lectures.

One of the lecturers before the Barber Surgeons was Alexander Re (or Rhead), a Scotchman, who graduated in 1620 at Oxford. His *Le tures on wounds* were published in 1634, those on *Surgical operations* 1637, and all his works in 1650. Read taught that a bullet may be made that it will make a poisonous wound, quoting as authority Querc tanus. Speaking of ligature of the artery, he says: "Ambrose Parre would have this mean to be used after the amputation of a member, who you may read; but in my judgment his practice is but a troublesome an dangerous toy; as he shall finde who shall go to make trial of it."

An important part of the business of the Corporation of Surgeons w

[1] The Dr. Caldwell referred to was Richard Caldwell, a graduate of Oxford and physician, and president of the college in 1570. Through his influence Lord Lumle founded and endowed a lectureship on surgery, which is still known as the Lumlei Bequest.

the examining and licensing of naval surgeons, both for the royal navy and for merchant ships. An account of such an examination is given by Smollett in his novel *Roderick Random*. Oliver Goldsmith also presented himself for examination in 1758, and the minutes of the court of examiners read as follows: "James Bernard, mate to an hospital; Oliver Goldsmith, found not qualified for dito."

In Scotland the University of Aberdeen was founded in 1494, and in 1505 had a professor of medicine.

King James III. is reported to have been "ane singular gude chirurgian, and there was none of that profession if he had any dangerous cure in hand but would have craved his adwyse." His method of obtaining practice must have been effectual, although it was an unusual one. We find in the accounts of the treasurer for 1511 an entry as follows: "Item to one fallow, because the King pullit forth his tootht, xiiii. 5."

The first charter of the Royal College of Surgeons of Edinburgh is dated July 1, 1505. It directs that no person shall make use of the craft of surgery or of barber craft within this burgh unless he is freeman and burgess of the same, and that he must be examined by the masters of the same craft upon the following points—namely: The anatomy, nature, and complexion of every member in man's body, and all the veins of the same. Every year one executed criminal was to be given to the college for anatomical purposes. No master of the craft shall take any apprentice who cannot write and read. Probably the most important provision was, that no person within the burgh shall make or sell any aqua vite except the masters, members, and freemen of the corporation.

By 1589 it had become the custom to admit barbers at a lower rate, but they had only the right to act as barbers, being specially forbidden to practise surgery, and were to have "na signe of chirurgie in their bughts or houses oppenlie or privatlie."

In the early part of the seventeenth century the leading British surgeons were Clowes and Lowe, already referred to, and John Woodall (156?–164?), who had served as an army surgeon, and about 1612 was elected surgeon to St. Bartholomew's Hospital and likewise surgeon-general to the East India Company, which last gave him the appointing of surgeons and mates to all the company's ships. In 1617 he published a work entitled *The Surgeons Mate or Military & Domestique Surgery. Discoursing faithfully & plainly the method and order of the Surgeons chest, the uses of the instruments, the vertues and Operations of the Medicines, and the exact Cures of Wounds made by Gun-shott, etc.* In 1628 he published a work entitled *Viaticum, Being the Path-Way to The Surgeons Chest. Containing, Chirurgical Instructions for the yonger sort of Surgeons, imployed in the Service of his Majestie, or for the Common-Wealth upon any occasion whatsoever. Intended chiefly for the better curing of Wounds made by Gunshot.*[1] His

[1] These works were afterward published together in folio in 1639, 1653, and 1658, a separate title-page being given to each work, but the pagination being continuous. The second title-page is often transferred in place of the first one, which has been lost, leading, on careless examination, to the erroneous supposition that they are two entirely distinct works of the same date.

works are not specially instructive, but are in parts very good reading In amputation he recommends tying large vessels, especially those of the thigh, if it can be done, but he seems to think that the surgeon will often fail, in which case, as well as for the smaller vessels, he recommends buttons of astringent and caustic powders.

In gangrene Woodall urged amputation in the mortified instead of the sound part—an old treatment which had then fallen into disuse He also suggests amputating as low as the ankle for disease of the foot instead of just below the knee, as was usually the case. He had never seen the actual cautery used in amputation.

In 1648, James Cook of Warwick published his *Mellificium Chirurgiae, or the Marrow of Surgery*, a manual which seems to have been popular, the sixth edition in 1717 being "licensed by the College of Physicians and fitted for the use of all sea-surgeons." In his description of amputation no mention is made of the ligature of arteries.

The greatest English surgeon of the seventeenth century was Richard Wiseman (1622–76), sometimes called the English Paré. He was apprenticed to a barber surgeon in 1637, served in the Dutch navy until about 1644, when he joined the army under Charles I., and was admitted to the Company of Barber Surgeons in 1651. He was a surgeon in the Spanish navy for three or four years, and in 1660 joined King Charles II. and was appointed one of his surgeons. In 1672 he published *A Treatise of Wounds* in an octavo of 277 pages. In 1676 this was enlarged and printed in a large folio volume under the title *Several Chirurgicall Treatises*. There were eight of these treatises—viz. I. Of tumors; II. Of ulcers; III. Of the diseases of the anus; IV. Of the King's evil; V. Of wounds; VI. Of gunshot wounds; VII. Of fractures and luxations; VIII. Of lues venerea. In 1686 this was published in folio, having the words "the second edition" on the title-page although it was really the third, and the so-called "third edition" (folio 1796), with the title *Eight Chirurgical Treatises, etc.*, was really the fourth. Other editions appeared in 1705, 1719, and 1734, and there is a spurious edition of 1692, which is really the original edition of 1676 with a new title-page.

Wiseman used the complex dressings of the period, but knew that simple measures produced equally good results. He used styptics and cauteries, and not the ligature, but he included the end of the cut vessel in one of the stitches through the lips of the wound. Being a personal friend of the king, he used his influence with him to promote the interests of the Barber Surgeon's Company. His works were never translated, and were very little known on the Continent, but they had a decided influence on the improvement of the art in England.

James Yonge (or Young) (1646–1721), a native of Plymouth and a naval surgeon, published in 1679 a little book of 120 pages entitled *Currus Triumphalis, ê Terebinthô. Or an account of the many admirable Vertues of Oleum Terebinthinae. More particularly, of the good effects produced by its application to recent Wounds." . . . . And lastly, A new Way of Amputation, etc.* He objected to Paré's method of ligatures in amputations, saying that it is "a way always tedious, often successless; and whatever vaunts the Author makes of it, it cannot be so secure as he pretends; it being liable (sometimes from the slackness,

otherwise from the too great straightness of the thred; sometimes from its smallness, cutting through, or from its weakness, giving way) to a new flux when not so tolerable to the Patient, or so easily cured by the Artist as at first; moreover, where two Vessels or more bleed in one Wound (which is very frequent), the one must be neglected, while the Ligature is making on the other." But he says: "The ligation of an Artery on other accounts, as in the Toothach, Epiphora, Aneurisma, &c., is not hereby impugned." On page 30 is to be found, perhaps, the first printed description of a tourniquet—"very useful in Amputations, especially above the knee; that is to say a wadd of hard linnen cloth, or the like, inside the Thigh a little below the *Inguen*, then passing a Towel round the member; knit the ends of it together, and with a Battoon, a Bedstaff, or the like; twist it, till it compress the Wadd or Boulster so very strait in the crural vessels that (the circulation being stopped in them) their bleeding when divided by the Excision, shall be scarce large enough to let him see where to apply his Restrictives." A similar tourniquet had, however, been used by John Morell in 1674 at the siege of Besançon. The "new way of amputation" is by a single flap, and is the first printed description of this method, which he says he learned from Mr. C. D. Lowdham of Exeter.

The *Compleat Discourse of Wounds, ... as also a Treatise on Gunshot Wounds in General*, by John Brown (surgeon to the king) (London, 1678, 4to), is a pompous, diffuse, tedious book, containing nothing of any importance.

Some curious illustrations of the English surgery of the middle of the seventeenth century are to be found in the *Diary of the Rev. John Ward, Vicar of Stratford-upon-Avon, extending from 1648 to 1679*, edited by Charles Severn (London, 1839, 8vo). For example: "A cancer in Mrs. Townsend's breast, of Alverston, taken off by two surgeons. . . . . First they cutt the skin cross and laid itt back, then they workt their hands in ytt, one above and the other below, and so till their hands mett, and so brought itt out. . . . . There came out a gush of a great quantitie of waterish substance, as much as would fill a flaggon. They put in a glass of wine and some lint, and so let itt alone till the next day; then they opened itt again, and injected myrrhe, aloes, and such things, as resisted putrefaction, and so bound itt up againe. . . . . The way how and where itt should be cutt was markt with ink by one Dr. Edwards."

"Gill told mee of a woman that had an apostheme about the side, and his master intended to trepan her on one of the ribs; whether it canne be;—I suspected itt to be a ly."

"The mountebank that cutt wry necks, cutt three tendons in one child's neck, and hee did itt thus; first by making a small orifice with his launcet, and lifting upp the tendon, for fear of the jugular veins, then by putting in his incision knife, and cutting them upwards; they give a great snapp when cutt. The orifice of his wounds are small, and scarce any blood follows."

"Gill said his Mr. Day hath amputated five armes, three leggs and somewhat else since he came to Oxford, and but two of all these died, and one was a person of sixty years att least."

"John Phillips his child had a red swelling in the forehead, I sup-

pose a varix or naevuss and itt was taken off by one of Coventry, by tying a hair about itt, and girding itt harder every day; in two weeks itt fetcht itt off."

A curious episode in the history of surgery in the first half of the seventeenth century is the controversy on the sympathetic or magnetic cure of wounds. This was a doctrine of Paracelsus, and in 1608 one of his followers, Goclenius, professor of medicine at Marburg, called special attention to it by his work, *Tractatus de Magnetica Curatione Vulneris*. His doctrines were objected to by the priests on religious grounds. Van Helmont wrote in defence of the doctrine, and his pamphlet was published without his knowledge in 1621. This created great excitement, and was translated into English by Walter Charleton, and published in 1560 under the title *A ternary of Paradoxes*. The cure was to anoint the bloody sword or other weapon which had inflicted the injury, or a stone or cloth dipped in the blood as it flowed from the wound, with a special ointment, and put it away carefully, applying nothing to the wound but a bit of wet lint. Goclenius thought the cure was a natural process; the priests thought it was due to magical formula and the aid of the devil; and Van Helmont undertook to prove that both were wrong, and that the so-called "weapon cure" was due to a certain mysterious sympathy precisely analogous to what, in later times, was called "animal magnetism."

The priests' view that weapon-salve cures are magical and sinful is given in the *Hoplocrismaspongus; or a sponge to wipe away the weapon-salve*, by William Foster, Parson, etc. (London, 1631), which was directed mainly against the celebrated Rosicrucian Robert Fludd, who replied with *Doctor Fludds answer unto M. Foster*, or the squesing of Parson Foster's sponge, ... wherein the sponge-bearer's immodest carriage and behaviour towards his brethren is detected, etc. (London, 1631). Fludd's book is much better reading than that of Foster.

Sir Kenelm Digby's discourse at Montpellier, on the cure of wounds by the powder of sympathy, published in 1657, was a famous book in its day. A less-known but equally curious book, by C. de Irvine, an army surgeon, was printed at Edinburgh in 1656 under the title of *Medicina Magnetica, or the rare and wonderful art of curing by sympathy*, and several other controversial pamphlets of the period are noted in the Index Catalogue of the Washington Library under the heading "Sympathy."

After the expulsion of the Moors from Spain there is little worth noting in the history of surgery in that country until after the middle of the sixteenth century. In 1488 it was ordered that those wishing to practise surgery must be examined under the direction of the Brotherhood of St. Cosme and St. Damian at Zaragoza, to which association was granted the privilege of dissecting the bodies of persons dying in the hospital recently established in that city. The surgeons were forbidden to order or to dispense internal remedies. At the end of the fifteenth century there were a few Spanish writers on syphilis, the best known being Villalobos.

The first celebrated Spanish surgeon was Francis Arcæus (1493–157?), whose treatise, *De recta curandorum vulnerum ratione*, written in his old age, was first published at Antwerp in 1574 and again at

Amsterdam in 1658. This was translated into English by John Read, and published at London in 1588, and a Dutch translation was published in 1667. Arcæus recommends the use of the trephine in fractures of the skull, describes with some minuteness the operation for excision of cancer of the breast and an apparatus for the treatment of club-foot, and advises mercurial inunctions on the joints for syphilis. His treatment of wounds is, in the main, that of John de Vigo.

Another Spanish surgeon of the sixteenth century of some repute was Bartoleme de Aguero (1531–97), professor of surgery at Seville, called by some the Spanish Paré, whose works were published in 1604 under the title *Tesoro de la verdadera cirujia*, and in other editions in 1624 and 1654.

Dionisio Daça Chacon (1510–159?), a surgeon in the Spanish army, serving in many countries and in the immediate service of Charles V., Philip II., Juan of Portugal, Don Carlos, and Don John of Austria, wrote his *Practica y teorica de cirujia* about 1580. This was the first comprehensive work in surgery written in Spanish. He used the cautery for checking hemorrhage in amputations, did not consider gunshot wounds poisonous, and abandoned the use of boiling oil in treating them after 1544, at the suggestion of a certain M. Bartolomeo, probably Maggius. His interesting report on the injury of the head of Don Carlos, in which he opposed Vesalius, who advised the trepan, is given with comments by J. M. Guardia in the *Gazette Méd. de Paris*, 1863, p. 41.

Andreas Alcazar, professor at Salamanca, published in 1575, in folio, his *Chirurgiae, ... libri sex*, and in 1582 his *De vulneribus capitis.*

Juan Fragosa, surgeon to Philip II., published *Erotemas quirurgicos* (Madrid, 1570, 4to), *De la Cirugia, etc.* (Madrid, 1581, fol.), *Tratado de cirugia sacado de la cirugia universal*, a little manual of questions and answers for students (1692), and *Cirujia universal, ... Y mas otros tres tratados . . . . Una summa de proposiciones contraciertos avisos de cirugia . . . . de las declaraciones acerca de diversas heridas y muertos . . . . de los Aphorismos de Hyppocrates tocantes a cirugia* (Alcala, 1592, and several later editions).

Cristobal Montemayor, surgeon of Kings Philip II. and III., wrote *Medicinia y cirugia de vulneribus capitis* (Valladolid, 1613; Saragossa, 1664).

Pedro Gago de Vadillo, a surgeon of Lima, published at Madrid, in 1632, *Discursos de verdadera cirugia y censura de ambar vias, y eleccion de la primera intencion curativa, y unicion de las heridas*, of which a third edition appeared in 1692.

Eighteenth Century.

At the beginning of the eighteenth century the only city in which there were any special opportunities for the study of surgery was Paris. There was no place for the barbers or the barber surgeons in the universities of Europe, and they had no institutions of their own in which any teaching worthy of the name could be obtained. Many of them had learned something in the camp or on the battle-field, which was the great practice school for the surgeons, as it had been for three centuries,

and there were but few surgeons of the time in England, France, or Germany who failed to gain experience therein. Nevertheless, this military experience contributed little to the advancement of surgery. Haeser says that the chief cause of the supremacy of French surgery in the seventeenth and eighteenth centuries was the wars undertaken by Louis XIV. and his successors, and that streams of German blood contributed in some degree to the foundation of the mastership of the French in the domain of surgery. There is a grain of truth in this statement, but it does not explain why the German and the English surgeons, who also saw more than enough of military surgery at this period, did not make the same progress as the French. Army service gives valuable experience to the man who has suitable preliminary training and is well grounded in anatomy, but for the barbers and barber surgeons of the eighteenth century such service increased their knowledge but little. It is true that the surgeons had learned something. They knew that shot-wounds were not poisonous and did not require cauterizing, and a large number of them probably also knew that ordinary wounds not involving the bones really required very little treatment. Nevertheless, they kept on prescribing and using their oils, ointments, plasters, vulnerary drinks, etc., the formulæ for which fill a considerable space in the surgical treatises of the day; and there is one special reason for this which the modern surgeon and historian usually does not fully appreciate. This reason was, that the charges of the surgeons in those times were based upon these applications, and this was also true for the ordinary practitioners of medicine: they compounded and dispensed their own remedies; their charges were made for the remedies and not for the visits; and hence the fees were in proportion to the number of the mixtures, draughts, unguents, etc. which were ordered for a particular case. The surgeons at the beginning of the eighteenth century, as a rule, used styptic powders and compression to check hemorrhage. Those who knew anything about the use of the ligature appear to have been afraid to trust it, and to have preferred the actual cautery. It was supposed to be necessary, or at all events desirable, to include a portion of the surrounding tissues with the artery to be ligated, for fear that the ligature might cut through the coats, and for the same reason the cord was often tied over a small pad instead of being made directly to encircle the vessel. In the army the surgeons necessarily practised medicine, but in civil life they were, as a rule, forbidden to use or prescribe the internal remedies, that being the business of the physician, who claimed exclusive rights in this respect.

At the beginning of the eighteenth century the leading surgeons in Paris were Georges Mareschal (1658–1736), surgeon of the Charité and first surgeon of Louis XIV. in 1703; Jean Méry (1645–1722), first surgeon of the Hôtel Dieu and the deviser of the operation of suprapubic puncture of the bladder; and Pierre Dionis (165?–1718), who had commenced teaching anatomy at the Jardin du Roy in 1673, and in connection with his lessons gave demonstrations of surgical operations on the cadaver. He had many pupils, and his *Cours d'opérations de Chirurgie*, first published at Paris in 1707, went through many editions and was translated into English, Dutch, and German, being a popular manual for fifty years. He advises the ligature of arteries in amputations, but says that at the

Hôtel Dieu the vitriol button is used instead. He advises the Marian operation in lithotomy, but says that he does not believe the high operation to be so dangerous as is supposed, and that he is assured that M. Bonnet has often practised this operation at the Hôtel Dieu with happy success. He tells at length the story of Frère Jacques up to that date, and apparently very fairly, showing the ignorance of the man, but saying that a surgeon who is a good anatomist may succeed by his method; which was true prophecy.

This Frère Jacques—Jacques de Beaulieu (1651–1719)—was an ignorant peasant who for a time was a servant of an Italian Incisor named Palloni. He became a monk, or, as Dionis says, a sort of a monk, and came to Paris in 1697, as he said, to show the surgeons how to perform lithotomy in a particular way. He was successful at first, and acquired great reputation, but soon had many deaths and left Paris, going in 1704 to Holland, where he taught his method to Rau, who improved it into what is generally known as the lateral operation. Frère Jacques himself improved his methods greatly after his visit to Paris, and spent the rest of his life as a wandering lithotomist, chiefly in Austria and Italy.

There is much good reading in Dionis: he does not confine himself to a mere description of the operations, but gives anecdotes which furnish a picture of his times and surroundings.

Gabriel le Clerc, a surgeon of Lille, published at Paris in 1692 a little book called *La chirurgie complète*, being a sort of quiz-compend with questions and answers. This became a popular manual, passing through eighteen editions and translations. He mentions the Hôtel-Dieu method of stopping bleeding arteries by vitriol buttons, and says that it is the custom of the Hôtel Dieu to employ a person to keep on the dressing with the hand for twenty-four hours after the operation.

B. Saviard (1656–1702), surgeon of the Hôtel Dieu, published in 1702 his *Nouveau recueil d'observations chirurgicales*, which was translated into English and published at London in 1740. This is a valuable collection of cases, containing a description of the tourniquet (using that name) as applied at the Hôtel Dieu in 1688 in a case of successful ligation of the femoral for a wound of that vessel. He refers to the pernicious atmosphere of the Hôtel Dieu and its effects on wounds, gives an interesting note on Frère Jacques, describes a case of dermoid cyst of the ovary and one of congenital absence of the penis, and gives details of some remarkable cases of lithotomy. It is a book worth having.

René Jacques Croissant de Garengeot (1688–1759) published his *Traité des operations de chirurgie* in 1720 (2d ed., 3 vols., in 1731). He was one of the best anatomists and surgeons of his time, and introduced many methods in details of operations for nasal polypus, hare-lip, strangulated hernia, etc.

Alexis Littre (1658–1726), whose name remains connected with the form of hernia first described by him, was a surgeon who devoted himself largely to pathological anatomy, and whose papers are contained in the Memoirs of the Academy of Surgery. He first proposed the operation of colotomy in 1710.

Nicolas Andry (1658–1742), dean of the medical faculty of Paris in 1724, is known in the history of surgery by his *L'Orthopédie, ou l'art de*

prévenir et de corriger dans les enfans les difformités du corps (Paris, 1741), being the first work in which the word orthopædia is used. It is a popular treatise on the care of children, and has very little to do with orthopædia as that word is now understood.

The most distinguished surgeon of the first half of the eighteenth century was Jean Louis Petit (1674–1750), who entered the army at the age of eighteen. In 1700 he settled at Paris and commenced giving a private course of lectures in anatomy and surgery. He invented the screw tourniquet, an appliance of almost as much importance as the ligature to the surgeon who has to amputate with unskilled assistance, devised herniotomy without opening the sac, and made an improvement in the circular method of amputation by cutting successively the skin and the muscles, instead of dividing them at one stroke according to the old method. This was carried still further by Desault, who divided the muscles on two levels. To Petit also is due the credit of having first demonstrated the mechanism of the occlusion of arteries in wounds, showing the chief process to be the formation of a clot, a part of which surrounds the end of the vessel and a part of which is a plug occupying the cavity; and of giving the first account of mollities ossium.

After the triumph of the medical faculty over the surgeons and barber surgeons in the middle of the seventeenth century, the College of St. Côme continued to give instruction, although it could not grant degrees, and in 1690 the number of the students was greater than the number of students in medicine, being over seven hundred. It was by no means poor, and in 1691 it began the construction of a new amphitheatre, which was completed in 1694.[1] In it were given lessons on anatomy and surgical operations, and similar teaching was given by a few ambitious young surgeons as a private enterprise. To become a member of St. Côme the aspirant must have been an apprentice for at least six years before he could present himself to perform his "grand chef d'œuvre," which, if successful, would make him a master surgeon. This "grand chef d'œuvre" was a long process of examination. The Washington Library contains a manual of preparation for it, in the form of a neatly-written manuscript, bound in four volumes, 8vo, "par C. Caulay, récu chirurgien juré le 24 juillet, 1737."

François de Lapeyronie (1678–1747) was a surgeon of Montpellier and demonstrator of anatomy in the School of Medicine. He came to Paris in 1714, soon became surgeon of the Charité, and first surgeon of the king in 1736. He was wealthy, and spent his money freely for the benefit of the Royal Academy of Surgery, which was organized in 1731, increasing in fame and prosperity for the next forty years, and through the agency of which, to a considerable extent, Paris became the great surgical centre of the world. J. L. Petit became the first director of the academy, and Sauveur-François Morand (1697–1773) its first secretary. Morand was an ingenious surgeon. He proposed amputation at the hip-joint and ovariotomy, and performed the high operation for stone, but he was an uneducated man, and was unable satisfactorily to perform the duties of secretary of the academy, which post he resigned in 1739. He was succeeded by Antoine Louis (1723–92), to whom the success of the academy and its marked influence on the progress of

[1] Corlieu: *La France Méd.*, 1878, xxv. p. 481.

surgery are to a great extent due. He was professor of physiology, and in 1757 became surgeon of the Charité, but he was not so much an operator or inventor as he was a learned historian, editor, and critic.

An indispensable work for the student of the history of surgery in France at this period is the collection of eulogies pronounced by Louis upon deceased members of the academy, published with notes and appendices by E. F. Dubois in 1859. These so-called *éloges* are judicial, critical, historical essays which are unequalled in surgical biography. At the commencement of his eulogy on Le Cat he remarks that these memoirs will form a part of the history of the Academy to be read in years to come, and that the truth must be told; and in this he was a true prophet. His *Œuvres diverses de chirurgie* were published in 1788.

Of the earlier members of the academy, besides those already named, the most distinguished were Le Dran and Le Cat. Henry François le Dran (1685–1773), the son of a surgeon, was educated in Paris, and became a master in surgery at the age of twenty-two. In 1724 he was appointed one of the four surgeons of the Charité, and established an anatomical school there, and in 1730 published his *Parallèle des différentes manière de tirer la pierre hors de la vessie*, which gave him much reputation. In 1734 he was sent as chief surgeon to the army, and published the result of his observations in 1737 in his *Traité . . . . sur les playes d'armes a feu*, which went through several editions. In 1742 he published a treatise on operative surgery. Le Dran made no great contribution to surgery, but he was a celebrated teacher and had many pupils from Germany, through whom his method became popular in that country.

Claude Nicolas le Cat (1700–68) was a surgeon of Rouen, who became surgeon-in-chief of the Hôtel Dieu of that city as the result of concours in 1729. He won many prizes from the Academy of Surgery in Paris, being specially skilled in "prize-essay writing," became professor of anatomy and surgery in the school established at Rouen in 1736, and attracted many students. He was a voluminous writer, but his papers which relate to lithotomy are the only ones of any special value. His reputation was greater abroad than it was at home.

Other surgical writers of this period are Guillaume Mauquest de la Motte (1655–1737), whose *Traité complet de chirurgie* (3 vols., Paris, 1722) was a very popular text-book; Georges de la Faye (1699–1781), whose *Principes de chirurgie* (Paris, 1739), an elementary handbook, passed through many editions and translations; and Elie Col de Villars (1675–1747), whose *Cours de chirurgie* appeared in 1738.

Dominique Anel (1678–1725 ?), a native of Toulouse, was a pupil of J. L. Petit, a surgeon in the French and Austrian armies, and a wanderer over Europe. In 1710 he ligated the brachial artery of a priest in Rome for traumatic aneurism, and this is claimed as a triumph of French surgery preceding the method of John Hunter. In fact, it was the operation performed and described long before by Guillemeau. In Genoa, in 1712, he devised his operation for lachrymal fistula and the syringe which still bears his name. In 1716 he was practising as an eye surgeon in Paris.

George Arnaud de Ronsil, a French surgeon, went to London prior to 1748, and remained there until his death in 1774. His *Dissertation*

on Hernia (London, 1748) was a paper of much importance. His *Mémoires de chirurgie* (London, 1762, 2 vols. 4to) contains matter of permanent value, and a curious paper, "Inconvéniens des Descentes particuliers aux Prêtres de l'Église Romaine," with reference to Leviticus xxi. 20. In 1732 he excised the cæcum and a part of the colon and ileum in a case of hernia.

Jean Baseilhac (1703–81), better known as Frère Côme, was the son of a surgeon and was educated as such. In 1729 he became a monk, but continued to practise surgery among the poor, and invented the lithotome cache. He published anonymously in 1751 an account of his operation, and in 1779 published a paper on the high operation. He was a skilful surgeon, and obtained greater success with his instrument than any other person has been able to do.

Pierre Brasdor (1721–97) was professor of anatomy and operative surgery in the College of Surgeons of Paris, and contributed to the Memoirs of the Academy of Surgery. His name is remembered in connection with his suggestion to treat certain aneurisms by ligation of the artery on the distal side of the tumor; which was first done by Wardrop.

Francis G. Levacher published in the Memoirs of the Academy of Surgery, in 1769, a paper on gunshot wounds, in which he, for the first time, showed that what were supposed to be the effects of the wind of a ball were really due to the ball itself.

Hugues Ravaton, a surgeon of the French army, published in 175(the best treatise on gunshot wounds which had yet appeared. His *Chirurgie d'armée* was issued in 1767, and his *Pratique moderne de la chirurgie* in 1770. He was the first to practise amputation by the double-flap method.

Jean Joseph Sue (1710–92), son of a Paris surgeon, and often mentioned as "Sue le jeune," was a teacher of anatomy, and in 1761 one of the surgeons of the Charité. He published *Éléments de chirurgie* (Paris 1755), *Traité des bandages* (Paris, 1761), and *Dictionnaire positif de chirurgie* (Paris, 1779).

Jean Louis Belloq (1730–1807), a professor of anatomy in Paris devised a number of instruments, among which was the canula for plugging the posterior nares still known by his name.

In the latter part of the century the leading surgeon in Paris was Pierre Joseph Desault (1744–95), who became surgeon of the Hôtel Dieu in 1788, and soon had a crowd of students following his public clinic, the like of which had never been seen before. He was a pupil of Louis and of Morand, and surgeon of the Charité in 1782. He was the first teacher of surgical anatomy in the modern sense of the term, made many improvements in the treatment of fractures, and contributed largely to the perfecting of surgical technique. He wrote almost nothing, but his pupil, Bichat, gave the substance of his teachings in the *Œuvres chirurgicales* (3 vols., 1798–1803). In 1792, Desault was arrested on the charge of having poisoned the wounds of some of the revolutionists who had been brought to the Hôtel Dieu. It was then but a step from the prison to the scaffold, and his pupils formed themselves into a deputation to defend him before the tribunal, their spokesman being Jean Pierre Maunoir, a young Swiss, afterward a celebrated surgeon in Geneva, whose pleadings prevailed and Desault was released.

The Hôtel Dieu of Paris was the "oldest, largest, richest, and worst hospital in Europe." In the latter part of the eighteenth century it contained over twelve hundred beds, and sometimes over three thousand patients, having four or five in one bed. The first distinct mention of surgeons in the Hôtel Dieu occurs in the records of the year 1539, in which it is ordered that the surgeon Jocot la Normand shall be retained to serve as surgeon in the Hôtel Dieu in place of George Barbas at a salary of about one hundred and eighty francs. By declaration of the managers in 1605 the surgeon must call a physician to see all the operations of surgery which he shall make within the Hôtel Dieu.

In 1654, Jacques Petit, master of surgery in Paris, was named surgeon of the Hôtel Dieu. This was an invasion, for up to that time the surgeons had been chosen from among the surgeons of the hospital. This Jacques Petit gave a course of anatomy to the pupils in the hospital, commenced the collection of instruments of surgery, and gave a sort of course of surgery at the bedside. This was the beginning of clinical surgery in this hospital and in France. He entered the hôtel at the age of thirteen, studied surgery there, and filled the place of surgeon-in-chief until 1705. The story was that he was more than sixty years in the house without putting his foot outside of it.

He was succeeded in 1705 by Méry, one of the most celebrated of the surgeons of this period. Méry was succeeded in 1722 by Thibault, he by Pierre Boudou, and he by Moreau, who was succeeded by Desault in 1786. Desault was succeeded by Pelletan in 1795.

The records of the Hôtel Dieu which escaped the fire of 1871 have been published by the Bureau of Public Assistance under the title *Collection de documents pour servir à l'histoire des hôpitaux de Paris* (Paris, 1881–87). In the second of these volumes, published in 1883, are given the deliberations of the governors of this hospital for the years 1768 to 1791, at the time when the hospital was badly overcrowded and complaints were being made by the surgeons of the management of the institution. Among other things, it contains a copy of the memoir of the Sisters in charge of the hospital, who in 1789 made a complaint against Desault to the effect that he was bringing pupils from the outside into the amphitheatre, which should be reserved for the pupils of the hospital alone, that the dressing of wounds was being interfered with, and that from two to three hundred strangers were admitted every day to hear his lectures. To this there is a long reply by Desault, showing that the complaints were in part ill founded, and urging that it is contrary to the public good to confine clinical instruction to the pupils resident in the house. The matter was investigated and the decision was given in favor of Desault. A very interesting description of the old Hôtel Dieu, showing the arrangement and character of the beds and furniture, overcrowding, etc., is given by Dr. J. B. Tenon (1724–1816) in his *Mémoires sur les hôpitaux de Paris* (1788, 4to).

François Chopart (1743–95) became professor in 1771, and in 1780 published, with Desault, the *Traité des maladies chirurgicales et des opérations, etc.*, which contains some of Desault's views, but which was wholly written by Chopart. His name remains connected with a form of partial amputation of the foot first described in 1792.

Raphael Bienvenu Sabatier (1732–1811) was a pupil of Petit, and

became professor of anatomy in the Royal College of Surgery. Hi principal work was his *De la médecine opératoire* (3 vols., 1798–1810

J. Fr. Deschamps (1740–1824), a pupil of Moreau and surgeon o the Charité, brought the Hunterian operation for aneurism into notic in France, and published an interesting historical treatise on lithotom in 1796.

François Quesnay (1694–1774), secretary of the Academy of Surgery wrote a work on the history of surgery in France which is full of error

Antoine Portal (1742–1832), professor of anatomy in the Royal Col lege of France, is the author of *Histoire de l' anatomie et de la chirurgi etc.* (7 vols., Paris, 1770–73), which is a useful book of reference.

Jean René Sigault studied surgery at Paris, and was received as mas ter in the school in 1770. In 1768 he presented a memoir to the Roya Academy of Surgery proposing to substitute the section of the symphysi of the pubis for the Cæsarian section. The proposal was not approved but he performed the operation in 1777 with success, and, as he ha become a doctor of the Faculty of Medicine, his new operation wa received with great enthusiasm by the members of the faculty. H published his *Mémoire* [*sur la section de la symphyse des os pubi pratiquée sur la femme Souchot*], *lu aux assemblées du 3 et du 6 décembr* 1777 (16 pp. 4to, Paris, 1777), and *Discours sur les avantages de l section de la symphyse* (8vo, Paris, 1778).

Georg Fischer, in his *Chirurgie vor 100 Jahren* (Leipzig, 1876), ha given a graphic picture of the condition of surgery and surgeons i Germany in the eighteenth century. The great mass of the peopl could only obtain surgical treatment from local barbers or from wander ing charlatans. The barber's apprentice could hardly write or eve read German. He learned how to shave, and then went from hous to house to serve his master's clients. He was also taught how t sharpen knives, spread blisters, and make lint. He performed the mos menial duties in the house, and occasionally one of the unhappy youth ran away and was duly advertised as a sort of runaway slave. Th people were grossly ignorant and intensely superstitious, believing i charms and magic; and the supply of this kind of medicine was no wanting. The cutters for stone and hernia, the cataract-operators, th bone-setters, and the travelling charlatans flourished everywhere, an the repeated edicts and ordinances issued by kings, nobles, and cit authorities to remove the complaints made by the physicians and to settl the difficulties merely prove the condition of the times and seem to hav had very little effect. Even the executioners competed with the sur geons. They were supposed to have special dealings with the power of evil, and in consequence to have special knowledge of the means o curing diseases considered to be due to witchcraft. A part of their busi ness was to dislocate joints by the rack or to break bones upon the wheel and hence it was supposed that they had special skill in the repair o fractures or of dislocations.

The practice of medicine was forbidden to the executioners in Prussia but in the year 1744 Frederick the Great granted to them permission t treat fractures, wounds, and ulcers, and when the Berlin surgeons com plained of this he issued an order saying that he had not permitted al executioners, but only the skilful ones, to practise, and if the surgeon

are as skilful as they pretend to be, every one will rather trust them than go to an executioner; but if the surgeons are ignoramuses, the public must not suffer, but must submit to be treated by the executioner rather than to remain lame and crippled.

In Germany the first surgeon of importance in the eighteenth century was Lorenz Heister (1683–1758), a native of Frankfort-on-the-Main. After studying medicine for four years at Giessen and other German universities, he went to Amsterdam in 1706 to study anatomy and surgery under Ruysch and Rau, and took his degree at Leyden in 1708. He gained experience in the army hospitals at Brabant and Flanders, made a tour into Great Britain, and in 1710 became professor of anatomy and surgery in the University of Altdorf. Here he lectured in Latin, but found the students and young surgeons so ignorant that he determined to print his system of surgery first in German, which he did at Nuremberg in 1718, as he states in his preface to later editions, and as given in bibliographies. I have, however, never been able to see a copy of this date, the earliest edition in the Washington Library having the imprint "Nürnberg, bey Johann Hoffmanns seel. Erben, im Jahr mdccxix." The work was a very popular one, and was translated into Latin, and thence into English under the title of *A general system of surgery* (1743; 7th ed. 1759), forming a thick quarto which is still excellent reading for a surgeon. Sharp says, in the preface of his *Critical enquiry* (1750), "Heister's Surgery is in every body's hands, and the character of Heister is so well established in England, that any account of that work is needless."

The other German university professors of surgery in the first half of the eighteenth century who are worthy of note are Haller, Platner, Mauchart, and Bass.

Albrecht von Haller (1708–77), a native of Bern, a pupil of Boerhaave, and one of the greatest physicians who ever lived, was professor of anatomy and surgery in the University of Göttingen from 1736 to 1753, and exerted a powerful influence on the development of anatomy, physiology, and surgery through his writings and his pupils, who came to him from all parts of Europe. He never performed a surgical operation on the living body, and his teaching in surgery was therefore purely theoretical. His *Bibliotheca chirurgica* (2 vols., Berne, 1774–75) is the most valuable work on the history and literature of surgery that has ever been published. He placed on a firm foundation the experimental method in dealing with surgical problems which was a little later so successfully employed by John Hunter, and which has contributed so much to our knowledge during the present century.

Johann Zacharias Platner (1694–1747) was professor of anatomy and surgery in the University of Leipzig from 1724 until his death. His *Institutiones chirurgiæ rationales tum medicæ, etc.* (Leipzig, 1745) passed through several editions and was translated into German and Dutch.

Burchard David Mauchart (1696–1751) studied at Tübingen, Altdorf, and Paris, and became professor of anatomy and surgery in the University of Tübingen in 1726. He devoted himself chiefly to the anatomy and diseases of the eye, and left no systematic treatise, but published a number of dissertations, which were collected after his death and published in three volumes (Tübingen, 1783–86).

Heinrich Bass (1670–1754) became professor of surgery in the Un versity of Halle in 1718, and in 1720 published his *Gründlicher Beric von Bandagen*, which was a favorite text-book for the next fifty years.

The great difficulty experienced by the government in providi competent surgeons for the troops led to the organization in 1724, Berlin, of a medico-chirurgical college, the Friedrich Wilhelms Institu In 1727 the Charité Hospital was founded by King Friedrich Wilhelm mainly to furnish clinical instruction to the students of this college. T supply, however, was not equal to the demand, for Frederick II. in l Silesian campaigns found an urgent need for skilled surgeons, and se some of his young officers to Paris and Strasburg to perfect their educ tion and to fit themselves to instruct others, and in 1743 he engag twelve French surgeons and assistants for the benefit of his troops. T results were not altogether satisfactory, because surgery was general considered to be distinct from and inferior to medicine; those who we destined to it were usually apprenticed to barbers, and the young su geons were, as a rule, men of an inferior class and of little educatio Finally, in 1795, as the result of urgent appeals from Görcke, the su geon-general of the Prussian army, the college was reorganized und the name of the Pépinière, and was devoted exclusively to the educati of medical officers for the army, retaining a special connection with t Charité.[1] An institution similar to the Pépinière, and for the same pu pose, was organized in Dresden in 1748 as the "Collegium Medic chirurgicum."[2]

The three German military surgeons of chief repute during this peri were Schmucker, Bilguer, and Theden.

Johann Lebrecht Schmucker (1712–86) was educated at the Pépinièr and sent to Paris for two years by the king to study under Le Dra He became the surgeon-general of the army, and published the resu of his experience in his *Chirurgische Wahrnehmungen* (2 parts, 177 and *Vermischte chirurgische Schriften* (3 vols., Berlin, 1776–82). H observations on wounds of the head and trephining and on amputatio are the most valuable of his writings.

Joh. Ulrich Bilguer (1720–96) studied at Strasburg and Paris, a entered the army in 1741. In 1757 he became the second surgeo general. In 1761 he published his *De membrorum amputatione rarissi administranda, etc.*, which passed through numerous editions. In this opposed the excessive tendency to amputation of his time, which w rather encouraged by Schmucker, and went to the other extreme. H *Chirurgische Wahrnehmungen* (Berlin, 1763; translated into Engli London, 1764) is his most important work.

Joh. Christ. Anton Theden (1714–97) was educated as a barber su geon, entered the army in 1737, and became third surgeon-general 1758 and first surgeon-general in 1786. His *Neue Bemerkungen u Erfahrungen zur Bereicherung der Wundarzneykunst und Medicin* (pu lished in 1771 and later editions, also in a French translation) conta accounts of some remarkable cases and surgical methods—so remarkab

[1] For details consult *Das Königl. preus. Med.-chir. Friedrich Wilhelms Institut*, von E. Preuss, Berlin, 1819, 8vo.

[2] For the history of this see *Das Königlich sächsische Collegium Medico-chirurgicum*, Dr. H. Frölich, im Der Feldarzt, Wien, 1877, No. 9.

in fact, as to excite some suspicion. For the ligature of arteries in amputation he substituted graduated compresses and the use of a certain wonderful lotion, the "arquebusade," composed of vinegar, alcohol, sugar, and dilute sulphuric acid, with some salt of lead. He strongly advocated methodical bandaging of the extremities, claiming by its use to have cured aneurism, varix, etc.[1]

In the last half of the century the two chief German surgeons were Von Siebold and Richter.

Carl Casper von Siebold (1736–1807), the son and apprentice of a surgeon, served for a time in French hospitals, and studied in Paris under Morand and in London under Pott and Bromfield. In 1769 he became professor of anatomy, surgery, and obstetrics at Würzburg, and soon acquired great reputation as an operator and clinical teacher. He was succeeded as professor and as surgeon of the Julian Hospital by his son, Joh. Barth. Siebold (1774–1814), who founded a journal called *Chiron*, devoted to surgery.

August Gottlieb Richter (1742–1812) became professor of surgery in Göttingen in 1766, and gave a new impulse to the study of that art in Germany, being the first to place it on a scientific basis. He was the best teacher of surgery in Germany in his day, had travelled extensively, was familiar with the good work then going on in France and England, and was an excellent writer. His *Abhandlung von den Brüchen* (1777–79) was the best book on hernia up to that date, and is still a classic. His history of surgery, *Anfangsgründe den Wundarzneykunst* (7 vols., 1782–1804), is a model in arrangement and style, but is not complete. His journal, the *Chirurgische Bibliothek* (15 vols., 1771–96), did more to develop surgery in Germany than any previous agency.

In Austria there is little worthy of note in the history of surgery until the latter part of the century. Gerard van Swieten (1700–72), a pupil and friend of Boerhaave, went to Vienna in 1745 and introduced clinical instruction, but the only surgeon of repute there in 1780 was Ferdinand von Leber, who is principally known by the investigation which he made upon the use of torture in jurisprudence. In 1785 the Military Medico-Chirurgical Akademie was founded by the emperor Joseph II. and placed under the direction of Brambilla, the object being the same as that of the Berlin Pépinière. It was connected with a hospital of twelve hundred beds, and received one hundred pupils, of whom twenty-four were residents in the house. The course of study was two years, and after passing the examination the student received the degree of doctor in surgery and the first vacant position in a regiment.

Giovanni Alessandro Brambilla (1728–1800) was an Italian who had studied in Pavia, and became a surgeon in the Austrian army and a special favorite of the emperor. He prepared the *Instruktion für die Professoren der k. k. chirurgischen Militärakademie* (Wien, 1784, 4to) and the *Instruktion für das k. k. Militärspital zu Wien* (Wien, 1784, 4to), which are curiosities in literature. The subjects and the order of the subjects to be taught are scheduled for each professor. He also published a large atlas of engravings of surgical instruments and a history of discoveries made by Italian anatomists and physicians, and exerted a power-

[1] For details as to the military surgery of these times see *Die Kriegs-Chirurgie der letzen 150 Jahre in Preussen*, von Dr. E. Gurlt, Berlin, 1875.

ful influence upon the progress of surgical education, although he mad no special improvements himself. A protégé of Brambilla was Joh Nepomuk Hunczovsky (1752–98), a barber's apprentice, who in 178 was appointed professor in the military medical school at Gumpendorf and published a compendium of surgical operations in 1785, of whic there were three later editions.

At the commencement of the eighteenth century Holland was a grea centre of medical instruction: Boerhaave had introduced clinical teach ing at Leyden, where Bidloo was also lecturing; Ruysch and Rau wer teaching in Amsterdam, and all who desired a complete education i surgery visited these schools.

Frederik Ruysch (1638–1731) commenced teaching anatomy in Ley den in 1666, and became famous for the perfection of his anatomica preparations, and especially for his injected preparations. His collectio was purchased by the czar, Peter the Great, but a part of it was los before it reached St. Petersburg. His numerous essays relate chiefly t anatomy, but contain some surgical observations.

Joh. Jac. Rau (1668–1719), a native of Baden and an apprentice of a barber surgeon in Strasburg, studied at Leyden and Paris and settle in Amsterdam, where he gave lessons in anatomy and surgery, to th great dissatisfaction of Ruysch. Having learned from Frère Jacque his method, he improved upon it and acquired great fame as a lithoto mist, but kept secret the details of his method, which was probably th lateral operation. He wrote nothing of importance, but had many dis tinguished pupils.

To this period belong Abram Titsingh (1685–?) of Amsterdam, city surgeon, surgeon of the admiralty, and master of the Surgeons' Guild, wh wrote works on lithotomy, spina bifida, venereal diseases, etc. whic were valuable in their day; Joh. Daniel Schlichting (1703–?), a lecture on anatomy and surgery in Amsterdam in the middle of the century said to have been the first to perform neurotomy for neuralgia of th fifth pair; Jos. Monnikhof (1707–87), appointed herniotomist of Am sterdam in 1752, who in 1775 published statistics of one thousand case of hernia, the first collection of this kind which had appeared; an Charles Faudacq (1691–175?) of Namur, who studied in Paris unde Petit, and published *Réflexions sur les playes, etc.* (Namur, 1735), an *Nouveau traité des plaies d'armes-à-feu* (Namur, 1746).

In Ghent the leading surgeon was Joh. Palfyn (1650–1730), educate in Paris, master of the Barber-Surgeons' Company in Ghent in 1698, an professor of anatomy and surgery in 1708. He is best known by hi *Anatomie Chirurgicale*, first published at Paris in 1726, and the firs treatise with the title of "Surgical Anatomy."

In the last half of the century the most celebrated teacher in Hol land was Peter Camper (1722–89), a native of Leyden, who became pro fessor of anatomy and surgery in Amsterdam in 1755 and professor i Gröningen in 1763. He was one of the most learned men of his time and a voluminous writer on anatomy, pathology, and medical jurispru dence. His treatise on calculus (1782), his dissertation on fracture of th patella and olecranon (1789), and his *Icones herniarum*, published afte his death by Soemmering, are valuable contributions to surgical literature

Among the Italian surgeons of the eighteenth century the bes

known are Benevoli, the two Nannonis, Lancisi, Valsalva, Tacconi, and Bertrandi.

Antonio Benevoli (1685–1756), a surgeon of Florence, discovered in 1722 that cataract is an opacity of the lens, and published his *Discorsi di chirurgia* in 1750. He discovered the principle of treating stricture of the urethra by dilatation.

Angelo Nannoni (1715–90) studied in Florence under Benevoli, and afterward in Paris and Rouen, and became chief surgeon of the hospital Santa Maria Nuova in Florence, attaining great reputation. His principal works are *Trattato chirurgico sopra la semplicità del medicare i mali d'attenenza della chirurgia* (1770) and *Memorie sopra alcuni casi rari di chirurgia* (1776).

Lorenzo Nannoni (1749–1812), son of Angelo, studied under his father, and became surgeon to the Hospital of the Innocents in Florence, where he gave clinical teaching. His principal work is *Trattato delle materie chirurgiche, etc.* (2d ed. 3 vols., 1793–94).

Giovanni Maria Lancisi (1654–1720), professor of anatomy at Rome and physician to Popes Innocent XI. and XII., is best known as an anatomist, but in his *De motu cordis et aneurysmatibus*, first published after his death in 1728, and in four later editions, he first clearly pointed out the difference between true and false aneurism.

Antonio Maria Valsalva (1666–1723) studied at Bologna, graduating in 1687, and became professor of anatomy in the university and surgeon to the Hospital of the Incurables in 1697. His chief work was *De aure humana tractatus* (1705).

Gaetano Tacconi (1689–1782), a native of Bologna, succeeded Valsalva as professor, and was surgeon to the hospital Santa Maria. He wrote *Notizia della ferita e della cura chirurgica seguita, etc.* (1738), and *De raris quibusdam herniis, etc.* (1751).

Giovanni Ambrogio Bertrandi (1723–65), son of a surgeon, studied at Turin and Paris, and in 1758 succeeded Lotteri as professor of surgery at Turin. His principal work is his *Trattato delle operazioni di chirurgia* (2 vols., 1763), which passed through several editions and was translated into French and German. His collected works, *Opere anatomiche e cerusiche*, were published after his death in fourteen volumes (1786–1802).

At the beginning of the eighteenth century there were few educated surgeons in London, and still fewer in the provincial towns; there was no special instruction in surgery to be obtained except through apprenticeship; and the facilities for studying anatomy were extremely limited.[1] When the monasteries were broken up by Henry VIII. the hospitals, which had previously belonged to the Church, became the property of the government. St. Bartholomew's was refounded in 1544, and placed under the superintendence of Thomas Vicary. This hospital had one physician and three surgeons, and these allowed their pupils and apprentices to attend and witness the practice. In 1662 there is mention of the presence of such students, but no formal system of lectures or teaching seems to have existed until after 1734, when leave was granted for

[1] See *The present state of chyrurgery*, by T. D. (London, 1703), in which, among other charlatans, reference is made to "The Unborn Doctor who cut off a vast number of women's breasts without loss of blood."

any of the surgeons or assistant surgeons to read lectures in anatomy in the dissecting-room of the hospital, and in 1763 a course of lectures on surgery was commenced by Percival Pott.

At St. Thomas's Hospital the first mention of an apprentice in the books is in 1561. The Barber Surgeons' Company was dissatisfied with the teaching in St. Bartholomew's and St. Thomas's hospitals, as it was losing money thereby, and in 1695 it made a special investigation into the complaints as to the manner of teaching in these hospitals, the surgeons to which declared that they had never taken an apprentice for a less term than seven years, but that some of the apprentices of other surgeons were allowed at times to witness their practice. In 1702 the governors of St. Thomas's Hospital took the matter of teaching into their own hands, and passed a law forbidding pupils or surgeons to dissect without permission of the treasurer. In 1703 it was resolved that no surgeon should have more than three "Cubbs;" in 1758 this term was altered to that of "Dressers." Lectures on anatomy and surgery began with Cheselden about 1720, and the Anatomical School may be said to have been fairly established about 1780.[1]

At the London Hospital the entry of the first student was in 1742, two years after the commencement of the hospital, and the Medical School was fully organized upon the model of the Edinburgh Faculty in 1785.

In the Orders of St. Bartholomew, dated 1633, it is directed "that no chirurgeon, or his man, doe trepan the head, dismember, or perform any great oper'con, but with the approbation or by the direction of the doctor." Special operators were appointed to cut for the stone at the hospitals, a Mr. Mullins doing this for St. Bartholomew's and St. Thomas's.

The Medical School of Guy's Hospital dates from 1769, in which year a resolution was passed by the governors that all surgeons of the hospital should occasionally give lectures to the pupils. It is also noted "No persons are to be entertained as pupils but such as have served five years to a regular Surgeon or Apothecary." At this time the schools of Guy's and of St. Thomas's were united, the surgical lectures being given at St. Thomas's and the medical at Guy's, and the two were known as the "United Hospitals."[2]

The ill-assorted union of surgeons and barbers formed by the act of 1540 was by no means harmonious, but the surgeons were unable to get rid of the barbers until 1745, when they agreed with Mr. Ranby, serjeant surgeon to the king, that he should procure the act of Parliament desired and that in return he should be made a member and be elected as master. The act of 1745, incorporating the "Masters, Governors, and Commonalty of the Art and Science of Surgeons of London," provided that it should be governed by a "court of assistants, composed of twenty-one members, whose office was for life, and who filled their own vacancies by election from the freemen of the company." Ten of this court of assistants were to be "examiners," whose office was also for life, and it was a penal offence for any one to practise surgery in London or within seven miles of the same without having been duly examined and licensed.

[1] See Prospectus, 1877–78, p. 11.

[2] See *A Biographical History of Guy's Hospital*, by S. Wilks and G. T. Bettany (London, 1892).

except that the rights of members of the College of Physicians to do so were not to be interfered with. The surgeons on their separation from the barbers took nothing with them except the Arris and Gale bequests; the hall, library, and plate remained with the barbers, and the new company had to provide a building for itself.

The condition of the company in 1790, as stated by Mr. Gunning, the master of the company, in his address at the close of his term of office, was as follows: "You have a theatre for your lectures, a room for a Library, a committee-room for your Court, a large room for the reception of your committees, together with the necessary accommodation for your Clerk. . . . . Your theatre is without lectures, your library room without books is converted into an office for your clerk, and your committee room is become his parlour, and is not always used even in your common business, and when it is thus made use of it is seldom in a fit and proper state." The next thing that appears in its history is a charter by George III., dated 1800, for consolidating the Royal College of Surgeons of London, in the preamble of which it is stated that "we are informed that the said Corporation of Masters, Governors, and Commonalty of the Art and Science of Surgery of London hath become and is now dissolved." This charter of 1800 simply reiterates the act of 1745.

Turning now to Scotland, we find that, in 1694, Dr. Archibald Pitcairn returned to Edinburgh from Leyden and endeavored to establish a medical school, which he intended, if possible, should surpass that of Leyden; and his first step was to induce a surgeon named Monteith to apply to the town council for a grant of dead bodies. As soon as the other surgeons heard of this, they also applied for the same privilege. The privilege granted to the surgeons had a clause to the effect "that the petitioners shall before the term Michaelmas, 1697, build, repair, and have in readiness one anatomical theatre, where they shall once a year (a subject offering) have one public anatomical dissection, as much as can be shown upon one body, and if the failzie, this presents to be void and null." This condition was complied with, and as the grant required that the body should be buried within ten days, the surgeons selected ten of their number, termed "operators," each of whom lectured one day on certain specified parts. In 1705 this system was changed, and one surgeon performed the duty, while the town council made this same surgeon professor of anatomy in the university. This was the commencement of the Medical School, although it was not until 1726 that it was fully formed through the influence of John Monro, an army surgeon who had settled in Edinburgh in 1700.

The leading surgeon in England in the first half of the eighteenth century was William Cheselden (1688–1752), a pupil of William Cowper, who began to lecture on anatomy in 1711 in his own house, and continued his teaching afterward at St. Thomas's Hospital, to which he was appointed assistant surgeon in 1718 and surgeon in 1719. In 1723 he published his *Treatise on the high operation for the stone.* Soon after he gave up this and perfected his "lateral operation for the stone," an improvement on the method of Frère Jacques and Rau, which soon became famous. He published a paper in the *Philosophical Transactions* on the formation of artificial pupil, which operation he was the first to

perform. In 1733 he became surgeon to St. George's Hospital at foundation, retired from St. Thomas's in 1738, and was one of the l wardens of the Barber Surgeons' Company immediately before the se ration of the surgeons and barbers, which took place in 1744–45.

His pupil, Samuel Sharp (1700–78), was elected surgeon to Gu Hospital in 1733. His *Treatise on the operations of surgery* (Lond 1739; 10th ed., 1782) and his *Critical inquiry into the present st of surgery* (London, 1750 and 1761, and translated into French, Spani and German) were celebrated in their day, and the *Critical inquiry* still a most interesting book to the surgeon. He devised the cylindri form of the crown of the trephine at present used, and contributed the knowledge of the anatomy of hernia.

William Bromfield (1712–92), surgeon to St. George's Hospital a surgeon to the king, published his *Chirurgical observations and cases*, two volumes, in 1773. These contain a number of valuable improveme in surgical methods, particularly as to bilateral lithotomy and the co pression of the subclavian artery above the clavicle on the first rib. also clearly points out the proper manner of ligating the artery in am tations, using the tenaculum to draw out the vessel, so that the nerve a other tissues should not be included, but he used a flat ligature. T he was a cool operator is shown in a case of lithotomy which he repo in the second volume at page 266, in which the intestines protruded i the bladder, and in which he first extracted three stones and then retur the intestines, with result of a perfect cure.

William Beckett (1684–1738), a London surgeon, wrote *Practi surgery illustrated and improved: being chirurgical observations . . . m at St. Thomas's Hospital* (London, 1740, 8vo), also *A collection of chir gical tracts* (London, 1740, 8vo), including a paper on new discove relating to the cure of cancers, published by him in 1711.

Benjamin Gooch, a surgeon of the Norfolk and Norwich Hospital 1771, published a volume of *Cases and practical remarks in surg* (London, 1758), and a collective edition of his works appeared in th volumes (London, 1792). He taught that in case of a wound of artery ligatures must be applied both above and below the wound

John Douglas (?–1743) was a Scotch surgeon who gave private l tures on surgery and anatomy in London about 1720, and in same year published an account of the performance of the high ope tion for the stone under the title of *Lithotomia Douglassiana*. He conceited and quarrelsome, and published two abusive pamphlets Cheselden, by whom he was completely overshadowed.

His brother, James Douglas (1675–1742), was a physician who sett in London about 1700, and was a distinguished anatomist and obstetrici He published a *Description of the peritoneum* (London, 1730, 4to), which he described the fold of the peritoneum which is still known his name.

To the first half of this century belongs one of the greatest itiner quacks known to history—viz. John Taylor (1708–67), who styled hi self "Chevalier, ophthalmiater pontifical, imperial, and royal." He born in Norwich, and in 1727 published a pamphlet on the mechanism the eye and on cataract. This he dedicated to Cheselden, from whom acknowledges that he had learned all that he knew about the matter, a

while the work was boastful, yet it was not more so than some other publications of that day. Soon after this period he appears to have given up all idea of respectable practice, and travelled far and wide over Europe, advertising himself extensively in every place that he came to, and publishing for the same purpose a large number of pamphlets referring to his wonderful cures. His autobiography, published in three volumes (London, 1762), is one of the curiosities of literature.

The principal English surgeon in the middle of the century was Percival Pott (1713–88), who became assistant surgeon of St. Bartholomew's Hospital in 1745 and surgeon in 1749. His contributions to surgery were numerous and important, especially those on hernia, injuries to the head, hydrocele, and the disease of the spine still known by his name as "Pott's disease." His *Treatise on ruptures* was published in 1756, his *Practical remarks on the hydrocele*, in 1762, and his *Remarks on that kind of palsy of the lower limbs which is frequently found to accompany a curvature of the spine*, in 1779. His *Chirurgical works* appeared in 1771, and there were four later editions, besides German, French, and Italian translations.

Alexander Monro (1697–1767), a pupil of Cheselden and of Boerhaave, became the first professor of anatomy in the University of Edinburgh in 1725; he also lectured on surgery and made great use of comparative anatomy. He founded the Royal Infirmary and gave clinical lectures on surgery, and was one of the best surgeons of his time. His writings relate chiefly to anatomy, but he also wrote important papers on aneurism, cataract, hernia, etc. He first tried to cure hydrocele by the injection of wine. His son, Alexander Monro [secundus] (1733–1817), succeeded him as professor of surgery, and held the chair until 1810, when he gave it over to his son of the same name, Alexander Monro [tertius] (1773–1859), who resigned in 1846, the professorship having thus been held by the three Monros for one hundred and twenty-one years. Although the chair was thus, after a fashion, hereditary, the talent did not descend to the third generation.

The next name to be mentioned is that of a man whose works mark an epoch in the development of surgery—John Hunter (1728–93), the youngest son of a Scotch farmer. His brother William, ten years older than himself, having received an excellent education according to the pattern of that time, settled in London and began to lecture on anatomy and surgery in 1746. In 1748, John Hunter, a rough, ignorant youth, decidedly addicted to low company and amusements, and not having shown the slightest taste for study, joined his brother, and was employed by him as an assistant in the dissecting-room which he had just established. He soon showed that he had found his proper field of activity, and after one year's experience was able to take charge of the pupils and to direct their work. William Hunter was a good classical scholar and a cultivated and polished man of the world, being in all these respects a complete contrast to his brother, who decided in favor of surgery as a career, and studied under Cheselden and Percival Pott.

The brothers entered into partnership in 1754, John devoting himself mainly to anatomy and to physiological experimentation. He also began to deliver lectures, but he was by no means attractive as either a writer or a speaker, and in the latter capacity his audience never

amounted to twenty persons. In 1761 he joined the army, going to the Spanish Peninsula, and remained with it until 1763, during which time he collected the observations contained in his treatise on gunshot wounds. On his return he began to teach anatomy and surgery to private pupils or apprentices, in which undertaking he was aided by his election as surgeon to St. George's Hospital in 1768. The remainder of his life was spent in this work, in investigations, and in the formation of the splendid museum which is now under the charge of the Royal College of Surgeons of London.

The name of John Hunter is familiar to all surgeons mainly through his recommendation that in cases of aneurism due to disease of the artery the artery should be tied in the sound parts between the aneurism and the heart; and aside from this and his great museum, very few persons except those who have prepared Hunterian orations or studied them could probably state with any clearness what it was that he did to acquire the reputation which he possesses. His work on comparative anatomy was the result of the dissection of over five hundred species of animals, in the course of which he made innumerable discoveries and anticipated many comparatively recent observers; and in comparative physiology it was even greater, being so far in advance of his times that it was not comprehended.

The treatise on *Blood, Inflammation, and Gunshot Wounds* is usually considered Hunter's greatest work and as embodying the results of the best part of his researches. This work was completed and given to the press during the last year of Hunter's life, and was not published until 1794.

The merit of Hunter's operation for aneurism does not, as Guthrie remarks, lie in the operative process, but in the principles upon which it is founded. The dangers arising from the application of the method of Antyllus to aneurisms produced by disease of the artery were in part due to the danger from hemorrhage when the artery, in a state of disease, is ligated, and in part to the suppuration and ulceration which followed the opening of the sac. But Hunter, reasoning upon experiments made by him in removing portions of the coat of arteries, and also upon the results which he had observed with regard to the establishment of a collateral circulation in cases where an artery had been obstructed, said: "If the artery, however, cannot be tied above the aneurism in the operation, where can it be tied if the limb be amputated? Why not tie it up higher in the sound parts, where it is tied in amputation, and preserve the limb?"

He first performed this operation in 1785, placing four ligatures on the artery with various degrees of tightness. The patient was cured of the aneurism, but died of other complications fifteen months afterward. In the second operation he applied only one ligature. Hunter probably was not aware of the full scope and value of his suggestion. He considered that the arteries which would admit of the operation were the carotids above the sternum, any of the branches of the external carotids, the subclavian after having passed the scaleni muscles, and the crural after having passed Poupart's ligament and given off the large muscular artery. He did not think the subclavian should be tied in axillary aneurism, because he would doubt as to the soundness of the artery, and the same with the femoral where it passes under Poupart's ligament.

His plan was opposed by Pott and Bromfield, the latter of whom said: "An extravagant proposition has been suggested by some people to tie up the principal trunk of an artery in the extremities. I once saw an attempt of this kind in a true aneurism of the ham, in which I shall only remark that the patient died; and I do believe that the embarrassments which occurred, as well as the event of the operation, will deter the gentleman who performed it from making a second attempt in a similar case." Hunter, after quoting this, says: "Now, unfortunately either for Mr. Bromfield or myself, this is the very case from which I have formed favorable ideas of the success of future operations of a similar nature."[1] Pott, writing in 1777, said: "As far as my observation and experience go, the operation for aneurism in the femoral and popliteal arteries, however judiciously performed, will not be successful; that is, will not save the patient's life. I have tried it myself more than once or twice. I have seen it tried by others; but the event has always been fatal. . . . . Nor have I ever seen any other operation that that of amputation which has preserved the life of the patient."

John Hunter was a tremendous worker. His labors were almost incessant. It is probable that his ignorance of what had been done by others was not so great as most persons have inferred from the fact that he rarely quotes or refers to others. It should be remembered that he was for a long time associated with his brother, who was certainly well acquainted with medical literature, and that he daily met men of culture and information, from whom he must have learned a certain amount of what was going on elsewhere. Some of his greatest work was effected through his pupils, Jenner, Abernethy, Astley Cooper, Physick, Everard Home, and others, all of whom were trained by him and perpetuated and expanded his teachings. Since his day mere mechanical dexterity, with some knowledge of ointments and plasters, is no longer thought sufficient for the stock in trade of a surgeon. The peculiar combination of work in anatomy, pathology, and surgery pursued by Hunter has been accepted to a large extent in England since his time as a model of training for a surgeon, and most of the modern leading surgeons have been in their younger days teachers of anatomy and of pathology; which fact has exercised a great influence upon the development and methods of teaching of surgery in England.

The successor of Hunter in English surgery was his pupil and enthusiastic admirer, John Abernethy (1764–1831). He was elected assistant surgeon to St. Bartholomew's in 1787 on the retirement of Mr. Pott, and then began to give private lectures on anatomy at his own house, and his success was such that the governors of St. Bartholomew's were induced to build a lecture theatre, where in 1791 he began to lecture on anatomy, physiology, and surgery.

Abernethy was the first to ligate the external iliac artery for aneurism, in 1796, and in 1798 he ligated the common carotid for hemorrhage. In 1793 he performed neurectomy for neuralgia of the arm commencing in the finger, and proved that after the removal of half an inch of the nerve reunion occurred and the skin of the finger resumed its natural sensibility.[2] He also introduced an improvement in the opening

[1] *Works of John Hunter*, edited by J. F. Palmer (London, 1837, vol. i. p. 547).
[2] See his *Surgical Works* (new edition, vol. ii., 1817, p. 205).

of lumbar abscesses by a method of incision which should admit the least possible amount of air. As he grew older he ceased to operate, and devoted himself more to the treatment of the general health of his patients. The work by which he is best known is his *Essay on the constitutional origin of local diseases.* Abernethy's reputation was not due to his books so much as it was to his lectures, which were dramatic in character, and given with certain eccentricities of manner and speech which considerably contributed to his reputation.

Henry Cline (1750–1827) was a pupil of Hunter, and became surgeon of St. Thomas's Hospital and president of the Royal College of Surgeons in 1823. He was lecturer on anatomy and surgery in the early part of the eighteenth century in the Aldersgate School, and contributed largely to the spread of the new ideas of Hunter. He wrote no special treatises, but had a number of distinguished pupils.

Sir William Blizard (1743–1835), a pupil of Hunter, became surgeon of the London Hospital in 1780 and founder of its medical school, to the cost of which he contributed largely. He was twice president of the College of Surgeons and founded the Jacksonian prize. He was one of the first to ligate the subclavian and the first to ligate the superior thyroid artery. His publications are chiefly in journals.

Sir Everard Home (1763–1832), the son of an army surgeon, was a pupil of John Hunter, who married his sister. He served for a short time in the army, returned to London and became Hunter's assistant, was appointed assistant surgeon to St. George's Hospital in 1787, and surgeon to the same in 1793, after Hunter's death. He was one of Hunter's executors and edited his works, was made a baronet in 1813, and resigned his position at St. George's in 1827. He was a voluminous writer, treating on strictures of the urethra, on ulcers, on diseases of the prostate, on comparative anatomy, etc., but lost his reputation as an author on account of the fact that he destroyed the greater part of the large collection of Hunter's manuscripts, of which he had obtained temporary possession, and which he used in preparing his own papers.

Other London surgeons of this century who should be mentioned are Sir Cæsar Hawkins, surgeon to King George II. and King George III., and surgeon of St. George's Hospital from 1735 to 1774; Thomas Gataker, surgeon of St. George's Hospital, who died in 1769; Joseph Warner (1717–1801), a pupil of Sharp, who became surgeon of Guy's Hospital in 1748, first ligated the common carotid in 1775, and whose *Cases in Surgery* (London, 1754; 4th ed., 1784) are still worth reading; and Sir James Earle (1755–1817), surgeon of St. Bartholomew's Hospital, who is best known by his *Treatise on hydrocele* (London, 1791) and *Observations on the operation for the stone* (London, 1793).

Among the distinguished provincial surgeons of this period may be mentioned Alanson, Park, White, Mynors, and Hey.

Edward Alanson (1747–1823) was a pupil of John Hunter, and surgeon of the Royal Infirmary at Liverpool from 1770 to 1794. He published *Practical observations on amputation and the after-treatment* (London, 1779), in which he recommended a method for obtaining a more complete covering for the end of the bone by cutting the muscles from below upward.

Henry Park (1744–1831) was a student of Pott and Le Cat, and was

surgeon of the Royal Infirmary at Liverpool from 1767 to 1798. His name is connected with the history of resection of the knee and elbow.

Charles White of Manchester published his *Cases in Surgery* in 1770, and first excised the head of the humerus in 1768.

Robert Mynors (1739–1806), a surgeon of Birmingham, published his *Practical observations on amputation* in 1783, and his *History of the practice of trephining the skull, etc.* in 1785.

William Hey (1736–1819), a distinguished surgeon of Leeds, published in 1803 his *Practical Observations in Surgery*, which passed through two later editions, and is still worthy of consultation. He described and named *fungus hæmatodes*. His name is connected with the form of saw devised by him for use in case of fracture of the skull, and with a mode of partial amputation of the foot.

At the end of the century the leading surgeons in Edinburgh were Benjamin and John Bell.

Benjamin Bell (1749–1806) was a pupil of Monro, and became a surgeon of the Royal Infirmary in 1772. In 1778 he published *A treatise on the theory and management of ulcers, etc.*, which went through numerous editions and translations. His *System of surgery* (6 vols., Edinburgh, 1783–87) also passed through many editions, and was translated into German and French, being the favorite systematic treatise for the next twenty years. He insisted strongly on the importance of saving skin in amputations and operations for the removal of tumors, in order to leave as little as possible of the surface of the wound exposed.

John Bell (1765–1820) graduated in medicine in Edinburgh in 1779, and in 1790 opened a private school for anatomy, surgery, and obstetrics. He was ambitious and energetic, and unsparing in his criticisms of his seniors, Monro and Benjamin Bell, thus causing opposition to his school, which, however, was popular and successful. His brother Charles was of great assistance to him in this enterprise. He published a treatise on anatomy which went through many editions: *Discourse on the nature and cure of wounds* (Edinburgh, 1795, with several editions and translations) and *The Principles of surgery* (3 vols., London, 1801–08, 4to), remarkable for the beauty of its engravings. He was the leading operating surgeon in Edinburgh for nearly twenty years. As the result of a bitter controversy with Gregory the number of surgeons at the Royal Infirmary was in 1800 limited to six, and Bell, with others, was excluded, and thus lost the opportunity for clinical teaching.

The story of the rise and progress of surgery in Ireland is told in the *History of the Royal College of Surgeons in Ireland and the Irish Schools of Medicine*, by Charles A. Cameron (Dublin, 1886).

In 1446, King Henry VI. established, by royal charter, a fraternity or guild of barbers for the promotion and exercise of the art of chirurgery. In 1572, Queen Elizabeth granted a second charter to the barbers and surgeons, ordering that they should be called the "Master Wardens and Fraternity of Barbers and Chirurgeons of the Guild of Saint Mary or Magdalene in our city of Dublin," and a third charter was granted in 1687 by James II., giving them full power of the guild over barbers within six miles of Dublin. There were, however, a certain number of surgeons who had no connection of any kind with the company, being army surgeons, or men of liberal education who had studied in the uni-

versities. In 1745 the company began to disintegrate, and in 1784 the union between the barbers and the surgeons was practically dissolved by the creation of the Royal College of Surgeons in Ireland. The beginning of teaching in Dublin is due to Sir Patrick Dun (1642–1713), president of the College of Physicians in Ireland, who left a bequest for "one or two Professors of Physick to read publick Lectures and make publick Anatomical dissections of the several parts of the human Body or Body's of other animals, to read Lectures of Osteology, Bandages, and operations of Chirurgery, to read Botanic Lectures, Demonstrate Plants publickly, and to read Publick Lectures on Materia Medica, for the Instruction of Students of Physick, Surgery, and Pharmacy." The teaching did not actually begin until 1744. The first surgical work published in Ireland appears to be *A Concise and Impartial Account of the Advantages arising to the Public from the general use of a New Method of Amputation* (Dublin, 1763, pp. 13). The second was *Observations on Wounds of the Head* (Dublin, 1776, pp. 177). This was published anonymously, but appeared in a second edition in 1778 under the name of the author, William Dease (1752–98), who was one of the most energetic founders of the Royal College of Surgeons, and one of the first to lecture in it. He was a very successful teacher, and in addition to his work on wounds of the head he published *An Introduction to the Theory and Practice of Surgery* (London, 1780, 8vo) and a work on midwifery which became a popular text-book.

In 1765, Sylvester O'Halloran (1728–1807), a surgeon of Limerick, who had studied in Paris, London, and Leyden, published at London *A Complete Treatise on Gangrene and Sphacelus; with a new Method of Amputation*, which was a valuable contribution to the literature of these subjects.

The Nineteenth Century.

The salient points in the history of surgery in the nineteenth century are the discovery of anæsthetics; the establishment of aseptic and antiseptic surgery upon the scientific foundation of the new science of bacteriology; the development of conservative surgery in the treatment of diseases and injuries of the extremities and of plastic and orthopædic surgery into a specialty; the rise and progress of abdominal and intracranial surgery; the entrance of two new nations, the United States and Russia, into the field of surgical discovery, literature, and teaching; the change in the methods of educating surgeons; the formation of surgical societies and associations; and the cosmopolitan character of the art developed by rapid international communication and by periodicals. The founding of museums like those of Hunter and Dupuytren, the removal of restrictions on the study of anatomy, the great advances made in pathological anatomy and experimental pathology, and the development of ophthalmology, otology, gynæcology, dermatology, and laryngology into their present highly specialized forms, have also exerted a strong influence upon surgery and the work of the general surgeon.

With the increasing accumulation of the people in cities have come increased demands and opportunities for surgeons, for increase of hospitals and medical schools, for skilled nursing, ingenious mechanics for the making of instruments and apparatus, and, in short, for many means of

carrying out suggestions for improvements through the aid of competent assistants.

More progress in the art has been made since 1800 than had been made in the two thousand years preceding that date, and this has been largely due to work done in the dissecting-room and in the laboratory. Consider for a moment some of the differences between the resources of the surgeon of 1800 and those of the surgeon of the present day. The surgeon of 1800 had little more knowledge than had Hippocrates of the chief causes of danger after operations, such as suppuration, pyæmia, or tetanus, and groped wildly for means to avoid them. He had no clinical thermometer, and could only guess at temperature and fever; no hypodermic syringe; no anæsthetic; no definite knowledge of the importance of blood-saving or of the best means of doing it. He knew nothing of plastic surgery, of tenotomy, of the ophthalmoscope, or of the use of the microscope in diagnosis, and had only just learned how to ligate arteries and to treat ordinary wounds in a simple and sensible way. The really great surgeon of that day who was bold, cool, and skilful could perform most of the great operations, such as amputation, ligature of large arteries, removal of tumors, Cæsarean section, and the like, but such men were few and far between.

At the beginning of the century London was the centre of surgical improvement and of surgical teaching, and the leading surgeons at that time were Abernethy, Cline, Blizard, Home, Astley Cooper, Lawrence, and Wardrop. The first four of these have been referred to in a previous section.

Astley Paston Cooper (1768–1841), a native of Norfolk, was apprenticed in 1784 to his uncle, William Cooper, surgeon to Guy's Hospital, and was soon transferred to Cline, then surgeon at St. Thomas's. He attended John Hunter's lectures and spent one winter at the Edinburgh Medical School, was appointed demonstrator of anatomy at St. Thomas's in 1789, and two years later became joint lecturer with Cline in anatomy and surgery. In 1800 he was appointed surgeon to Guy's on the resignation of his uncle. In 1805 he ligated the common carotid for aneurism, and in 1817 the abdominal aorta. In 1820 he performed a simple operation on King George IV., which resulted in his being made a baronet. In 1825 he resigned his lectureship at St. Thomas's and induced the formation of a separate medical school at Guy's, in which his pupil, Aston Key, lectured on surgery, and his nephew, Bransby Cooper, on anatomy. He was an extremely skilled anatomist, and some of his most valuable contributions are connected with his work in this direction. Among them may be mentioned his treatises on hernia (in two parts, 1804–07), the second edition of which appeared in 1827, the illustrations to which are said to have been so expensive that he lost a thousand pounds by the publication. His book on *Dislocations and Fractures of the Joints* was published in 1822; his *Lectures on the Principles and Practice of Surgery*, with additions by Tyrrell, in three volumes, in 1824–27: the eighth edition of this appeared in 1837; and his *Illustrations of Diseases of the Breast*, Part I., in 1829; his observations on the *Structure and Diseases of the Testes* in 1830; and his work on the *Anatomy of the Breast* in 1840. He seems to have read little, his books contain few references to the work of other men, and his reputation and influence

were due more to his personality and his great skill as an operator than to his contributions to science or practice.

William Lawrence (1783–1867), the son of a surgeon, was a pupil of Abernethy and his demonstrator of anatomy for twelve years. He became a member of the College of Surgeons in 1805, won its prize for an essay on hernia in 1806, was appointed assistant surgeon to St. Bartholomew's Hospital in 1813, and in 1815 became professor of anatomy and physiology at the College of Surgeons. His lectures were considered to flavor of infidelity, and led to a sharp controversy, which ended by his recanting the objectionable opinions and withdrawing his book, *On the History of Man*, from sale as far as he could. He was connected with the Aldersgate Medical School, and in 1823 succeeded Abernethy as lecturer on surgery at St. Bartholomew's. His principal contributions to surgical literature are his *Treatise on Diseases of the Eye* (1833) and his *Lectures on Surgery*, published in 1863. He was a skilled anatomist, an eloquent lecturer, and an erudite author.

James Wardrop (1782–1869), a native of Scotland and educated in Edinburgh, came to London in 1809. In 1826 he founded a hospital under the title of the "West London Hospital of Surgery," and in the same year, in conjunction with Mr. Lawrence, gave a course of lectures at the Aldersgate Street School. His abusive articles in *The Lancet* in 1826–27 probably prevented him from having any official connection with the colleges. In 1828 he was made surgeon to the king. He wrote for *The Lancet* (1834, vol. ii.) a series of grossly personal and abusive papers entitled "Intercepted Letters," purporting to be written by Halford, Brodie, McMichael, and others, after which the heads of the profession in London had as little as possible to do with their author. In 1835 he joined the Hunterian School of Medicine and gave a course of lectures on surgery. His best-known work is that on the *Morbid Anatomy of the Eye*. His name in the history of surgery is chiefly connected with the operation first proposed by Brasdor for the cure of aneurism by placing a ligature on the distal side of the tumor, which operation Mr. Wardrop performed successfully in two cases of aneurism of the carotid artery, and in one case of aneurism of the innominate artery, in which he tied the subclavian.

The following surgeons also belong to the early part of the century:

Joseph C. Carpue (1764–1846), who in *An Account of two Successful Operations for Restoring a Lost Nose, etc.* (London, 1816, 4to), introduced rhinoplasty by the Indian method, and recalled attention to the high operation for stone in his excellent historical sketch, *The History of the High Operation for the Stone* (London, 1819).

Samuel Cooper (1780–1848), surgeon of the University College Hospital from 1831 to 1848, published his *Surgical Dictionary* in 1809, the first comprehensive and complete work of the kind in existence, and the continued popularity of which is shown by the fact that its eighth edition was published in 1861–72. Every edition is valuable to the student of the progress of surgery in the nineteenth century.

Alexander Copland Hutchinson, a naval surgeon, published *Practical Observations on Surgery* in 1816 (2d ed. 1826), and *Some further Observations on the subject of the proper period for Amputating in Gunshot Wounds, etc.*, in 1817.

Charles Aston Key (1793–1849), a pupil of Astley Cooper, whose niece he married, became demonstrator of anatomy at St. Thomas's Hospital in 1820, assistant surgeon to Guy's Hospital in 1821, surgeon to the same in 1824, and professor of surgery in its school in 1825. He ligated the subclavian artery in 1825, and tied the carotid for aneurism in 1830; introduced the use of the straight staff in lithotomy, and the method of dividing the stricture external to the sac in strangulated hernia, and was one of the most popular teachers in London.

From 1820 to 1835 the leading London surgeons, in addition to those already referred to, were Brodie, Bell, and Travers.

Sir Benjamin Collins Brodie (1783–1862) was a native of Wiltshire, England. He studied in London, and began to assist in teaching at the Windmill Street School in 1805, when he was twenty-two years of age. In 1803 he became the pupil of Sir Everard Home, and in 1808 assistant surgeon at St. Thomas's Hospital, where, in 1822, on the death of Mr. Griffiths, he became full surgeon, from which position he retired in 1840. He devoted himself largely to physiological experiments, some results of which appeared in the celebrated Croonian Lecture, delivered in 1810, on the influence of the brain on the action of the heart, in which he reported the results of the use of the woorara poison, and in a paper published in 1814 on *The Influence of the Pneumogastric on the Secretions of the Stomach*. Of his surgical writings, the first, and perhaps the most important, is his *Pathological and Surgical Observations on the Diseases of the Joints*, published in 1818, and appearing in a fifth edition in 1851. His lectures *On Diseases of the Urinary Organs* appeared in 1832, a fourth edition being issued in 1849. In 1846 he published a volume of lectures on various subjects in pathology and surgery. His complete works, with an autobiography, are published in three volumes (8vo, London, 1865). He devoted himself to the scientific side of surgery rather than to operations, although he was a very successful operator, and for over thirty years was recognized as the head of the medical profession in London.

Sir Charles Bell (1778-1842) was a younger brother of John Bell of Edinburgh, under whom he studied and whom he soon began to assist in the teaching of anatomy. In 1804 he went to London, where he began to teach in his own house in 1807, after which he associated himself with Mr. Wilson in the Great Windmill Street School, where he came into competition as a teacher with Cline, Cooper, and Abernethy, and met with great success. In 1812 he began to deliver clinical lectures in the Middlesex Hospital, to which he was appointed surgeon in 1814. In 1836 he accepted the chair of surgery in the University of Edinburgh, which he held until his death. His publications were voluminous, and include his *System of Operative Surgery* (2 vols., 1807–09), his paper on *Gunshot Wounds* (in 1814), his *Surgical Observations* (2 vols., London, 1816–18), and his *Illustrations of the Great Operations in Surgery, etc.* (in 1821). His fame, however, is mainly due to his papers relating to the nervous system, the result of careful and long-continued experimental work. His *Idea of a New Anatomy of the Brain*, printed in 1811, is a pamphlet of 36 pages which forms an epoch in the history of discoveries relating to the structure and functions of that organ. He was a skilled artist, a dexterous operator, and a conscientious and popular teacher, whose fame has increased instead of diminishing since his death.

Benjamin Travers (1783–1858) was a pupil of Astley Cooper, prosector of anatomy at Guy's Hospital, and surgeon of St. Thomas's Hospital in 1815. He was a skilled ophthalmologist, and his *Synopsis of the Diseases of the Eye* (1820) was the best systematic treatise on that subject which had yet appeared in English. His tastes led him to the scientific rather than to the practical aspect of surgery, and his treatises on *Constitutional Irritation* (1824), *A further Inquiry concerning Constitutional Irritation and the Pathology of the Nervous System* (1834), and *The Physiology of Inflammation* (1844) are specimens of physiologico-pathological investigation of the highest order of merit. He contributed some valuable papers on aneurism and the ligature of arteries to the *Medico-chirurgical Transactions*, and one on wounds of the veins in the *Surgical Essays*, published by Astley Cooper and himself in 1818–19. He introduced the use of mercury in non-specific iritis and in other forms of inflammation. Of all the English surgeons of this period, there are none whose writings are more interesting to-day than are those of Travers.

In Edinburgh there was no surgeon of special note engaged in teaching after John Bell was excluded from the infirmary and gave up his school. No separate chair of surgery was established in the university until 1831, owing to the persistent opposition of the second Monro, who claimed to be professor of surgery as well as of anatomy. A chair of surgery was instituted in the College of Surgeons in 1804, which was maintained until the chair was created in the university in 1831, and this was filled by Dr. John Thomson (1765–1846), who became surgeon of the Royal Infirmary in 1800, and began to give clinical lectures therein on surgery in the private theatre in 1801, this being then the only separate course on this subject given in the city. In 1806 a chair of military surgery was instituted in the university, to which Dr. Thomson was appointed. His *Lectures on Inflammation, etc.* (Edinburgh, 1813) passed through several editions and translations, and his *Report of Observations made in the British Military Hospitals in Belgium after the Battle of Waterloo, etc.* is of interest to army surgeons.

A chair of clinical surgery was created in the university in 1803, which was filled by the appointment of James Russell, a surgeon of the Royal Infirmary, who published in 1794 *A Practical Essay on a certain Disease of the Bones termed Necrosis* (Edinburgh, 8vo), and in 1833, after his retirement, *Observations on the Testicles.*

Sir George Ballingall (1780–1855) entered the army in 1806, and became professor of military surgery in the university in 1823. His principal work is his *Outlines of the course of lectures on Military Surgery, etc.*, published in 1833, which reached a fifth edition in 1855.

Here also may be mentioned John Hennen (1779–1828), a distinguished English military surgeon, a native of Ireland, who studied in Dublin and Edinburgh, and entered the army in 1800. His chief work is *Observations on some important points in the practice of Military Surgery, etc.* (Edinburgh, 1818), and subsequent editions, called *Principles of Military Surgery* (Edinburgh, 1820).

In Glasgow at the beginning of the century the leading surgeon was John Burns (1775–1850), who was the first lecturer on anatomy who was unconnected with the university. His *Principles of Surgery* (2 vols.,

London, 1829–38) was dry and had no success, but his *Principles on Midwifery* reached a tenth edition. In 1815 he was appointed Regius professor of surgery in the University of Glasgow, and held this position until his death.

Allan Burns (1781–1813) was a brother of John, whose demonstrator he became in the anatomical school. He first described the falciform process of the fascia lata in its relations to femoral hernia in a paper which he published in the *Edinburgh Medical Journal* in 1806. His *Observations on the Surgical Anatomy of the Head and Neck* (Glasgow, 1811) is a valuable surgical work, which contains, in addition to the anatomy, accounts of numerous cases of tumors in this region, a discussion on the treatment of aneurism, etc. He suggested the ligature of the innominate artery, and it was this suggestion which led to the first performance of the operation by Mott in 1821.

Between 1825 and 1840 four surgeons in Edinburgh became distinguished, and two of them were transferred to London to take high places there. These four were Lizars, Liston, Fergusson, and Syme.

John Lizars (1783–1860) was a pupil of John Bell, and began to teach anatomy in a private school in 1815. In 1831 he became professor of surgery in the Royal College of Surgeons. He was the first in Scotland to ligate the innominate, and the second to perform ovariotomy, an operation which became known mainly through his *Observations on Extirpation of Diseased Ovaria* (Edinburgh, 1825, fol.). His name is also connected with early operations for excision of the jaws. In 1839 he ceased teaching and devoted himself to private practice. He was a skilled anatomist and a brilliant and daring operator.

Robert Liston (1794–1847), a native of Scotland, was educated in Edinburgh and London, and began to teach anatomy in 1818. In 1823 he gave up this teaching in favor of Syme and devoted himself entirely to surgery. He became surgeon of the North London Hospital and professor of clinical surgery in University College, London, in 1834, and rapidly achieved a great success. He was possessed of great personal strength and was a brilliant operator, having the reputation of being the most dexterous surgeon of his time. His method of flap-amputation became very popular, and he made numerous contributions to the surgery of amputation, aneurism, lithotomy, and lithotrity. He would amputate the thigh with only the aid of one person to hold the limb and tie the ligatures, compressing the artery with his left hand, using no tourniquet, and doing all the cutting and sawing with the right. A large part of his skill and success was due to his knowledge of anatomy, which he kept up by dissections throughout his life. He excised the upper jaw for a formidable tumor in 1836, and the success in this instance brought to him a crowd of cases. His rashness is exemplified in the celebrated case in which he punctured an aneurism of the carotid, supposing it to be an abscess, although his house-surgeon had told him that the tumor pulsated. His principal publications were his *Elements of Surgery*, published in 1831, and his *Practical Surgery*, in 1837, both of which works went through several editions.

William Fergusson (1808–77), a native of Scotland, was educated at Edinburgh, being a pupil of Robert Knox. In 1831 he was elected surgeon to the Edinburgh Royal Dispensary, being at this time lectur-

ing on surgical anatomy in association with Knox, and was the first to ligate the subclavian in Scotland. In 1840 he accepted the professorship of surgery at King's College, London. In 1855 he was appointed surgeon extraordinary, and in 1867 serjeant surgeon to the queen. For many years he was the leading surgical operator in London. He resigned his professorship of surgery in 1870, but remained clinical professor of surgery and senior surgeon at King's College Hospital until his death. He was created a baronet in 1866. His special contributions to the art were largely in the line of what he called "conservative surgery," a term which he first applied in 1852 to the avoidance of amputation by means of resections and to the removal of no more than is absolutely necessary in cases of diseases of the bones. His name is especially associated with operations of hare-lip and cleft palate, with operations on the jaws, the excision of joints, and with lithotomy and lithotrity. His principal contribution to literature is his *System of Practical Surgery* (London, 1842; 5th ed. 1870). He also contributed many valuable papers to the periodicals. His lectures on the *Progress of Anatomy and Surgery during the Present Century* (1867) are extremely interesting to the student of the history of surgery.

James Syme (1799–1870) was a pupil of Dr. Barclay, and when only nineteen years old was entrusted with the charge of his cousin Liston's anatomical rooms, in which he began to teach in 1822. In 1825 he began to teach surgery, but, having quarelled with Liston, he had no chance to obtain an appointment in the Royal Infirmary, and therefore started a private hospital. When he succeeded Russell in the clinical chair in the university, he became one of the surgeons of the infirmary in 1833, and after Liston went to London in 1834 the greater part of the operative surgery of Scotland fell into his hands. In 1831 he published his treatise on the *Excision of Diseased Joints*, which was the first systematic attempt to show that excision ought, in most cases, to supersede amputation, and it had the greatest influence in bringing about this change in practice. The first edition of his *Principles of Surgery* was published in 1822; the fifth edition in 1863. This is an extremely concise work, and the fifth and last edition is smaller than the first. In 1847 he published his *Contributions to the Pathology and Practice of Surgery*, in which he gives an account of the first eight cases of amputation at the ankle-joint by the method which is still known by his name. The date of his first case of this kind is September 8, 1842. In 1847 he accepted a call as surgeon to University College, London, on the death of Liston, but he did not find the place satisfactory, and four months later he returned to Edinburgh. He was a bold, cool, and skilful operator but not a rash one. Among his most remarkable operations may be mentioned those for aneurism by incision of the tumor and ligation above and below, which operation he performed in cases of aneurism of the carotid, the axillary artery, and the iliac artery.

In 1835 the greater part of the medical teaching in London was still given in private schools having no connection with hospitals, the oldest and best known being the Windmill Street and Aldersgate Street Schools. The Great Windmill Street School was established by William Hunter about 1746, and numbered among its teachers the two Hunters, Baillie, Cruikshank, Wilson, Mayo, Shaw, Brodie, Charles Bell, Carpue, and

Cæsar Hawkins, but was finally destroyed by the establishment of the London University in the vicinity of the Middlesex Hospital in 1836. The Aldersgate School was also of old date, and numbered among its teachers Wardrop and Lawrence.

The hospital schools of Guy's and St. Thomas's, which had been united in 1768, the surgical lectures being given at St. Thomas's and the medical at Guy's, were practically separated in 1825, and entirely so in 1836.

After Liston and Fergusson came to London clinical hospital teaching increased rapidly in favor and importance; the hospital schools began to flourish and the private schools to disappear. At this period, in addition to those already mentioned, the principal surgeons were Guthrie, Green, Lloyd, South, Morgan, Stanley, and Hawkins.

George James Guthrie (1785–1856), an apprentice of a London surgeon, was appointed hospital mate in the army, and sent to the York Hospital at Chelsea when he was only fifteen years old. He became assistant surgeon in 1801, accompanied his regiment to North America in 1806, and served during the War of the Peninsula in Spain, becoming surgeon of the forces in 1810, and commanding three divisions of cavalry at the battle of Albuera. He was placed on half pay in 1814, and went to the battle of Waterloo, where he performed an amputation at the hip-joint on a Frenchman, and tied both ends of the peroneal artery, being successful in each case. He became assistant surgeon to the Westminster Hospital in 1823, surgeon to the same hospital in 1827, and professor of anatomy at the Royal College of Surgeons in 1828. His treatise *On gunshot wounds of the extremities requiring the different operations of amputations, etc.*, 1815, urging prompt amputation, marks an epoch in the history of military surgery; the sixth edition, including additions relating to the Crimean War, was printed in 1855. In addition to this he published *A treatise on the operations for the formation of an artificial pupil, etc.* (1819), *Lectures on the operative surgery of the eye* (1823; 3d ed. 1838), and *On injuries of the head affecting the brain* (4to, 1842; 2d ed. 1847). He also contributed many papers to medical journals.

Joseph Henry Green (1791–1863), a nephew and pupil of Henry Cline, became surgeon to St. Thomas's Hospital in 1820 and professor of surgery in King's College in 1830. In 1837 he resigned his professorship, and in 1852 his position at St. Thomas's. His publications were chiefly short papers in medical journals.

Eusebius Arthur Lloyd (1795–1862), a pupil of Abernethy, became assistant surgeon to St. Bartholomew's in 1824, and surgeon in 1847, from which position he retired in 1861. He gained the Jacksonian prize for 1818 by his essay on scrofula, enlarged and published in 1821.

John Flint South (1797–1882), an apprentice of Henry Cline, was admitted as a member of the Royal College of Surgeons in 1819, after which he studied in Germany, and on his return became demonstrator at St. Thomas's Hospital, then lecturer on surgery, and ultimately surgeon to the hospital. He is best known by his translation of Chelius's *System of surgery*, to which he added a large number of notes, greatly increasing the value of the work. He also collected materials for a *History of the craft of surgery in England*, which was published in 1886,

after his death, under the supervision of Mr. D'Arcy Power, and is a valuable book of reference. Through his efforts the remains of John Hunter were transferred to Westminster Abbey, and the inscription on the tablet is from his pen.

John Morgan (1797–1847), a pupil of Astley Cooper, assisted Mr. Key as demonstrator of anatomy in a private school, was in 1821 appointed assistant surgeon, and in 1824 surgeon, to Guy's Hospital, in the school of which he lectured on anatomy and surgery. In the latter part of his career he devoted himself to ophthalmology. He was an excellent operator, ligated the iliac artery several times, was one of the first to perform flap-amputations, and was the first to use metal sutures in wounds; he was also one of the first to perform ovariotomy. His principal work was *Lectures on diseases of the eye* (1839). He also assisted Dr. Addison in *An Essay on the operation of poisonous agents in the living body* (1829).

Edward Stanley (1791–1862) studied at St. Bartholomew's, to which he became assistant surgeon in 1816 and surgeon in 1838. He was twice president of the Royal College of Surgeons. His principal publication was *A Treatise on the diseases of the bones* (1849).

Cæsar H. Hawkins (1798–1884), prosector of anatomy in the school of Great Windmill Street for many years, became surgeon of St George's Hospital in 1829, and retired in 1861. In 1861 he was president of the Royal College of Surgeons, and in 1862 serjeant surgeon to the queen, succeeding Brodie, being the fourth of his family to hold this position. His works were collected and published in two volumes in 1874.

Among the distinguished provincial surgeons of the century were George Freer of Birmingham, author of *Observations on aneurism and some diseases of the arterial system* (4to, 1807); Joseph Hodgson of Birmingham, best known by his treatise on *Diseases of the arteries and veins* (London, 1815; translated into French and German); John H James (1789–1869) of Exeter, the author of the Jacksonian prize essay for 1818 on inflammation, and the second to ligate the abdominal aorta John Green Crosse (1790–1850) of Norwich, author of the Jacksonian prize essay for 1825 on urinary calculus, and whose fine library of diseases of the urinary organs came into the possession of Professor S. D. Gross, and was destroyed by fire in Louisville; John Ga (1791–1870) of Swindon, a pupil of Abernethy; John Smith Sode (1780–1863) of Bath; George M. Jones (180?–1861) of Jersey, a brilliant operator, who performed excision of the knee-joint without knowing of Fergusson's operation a few weeks before, excised the hip and ankle-joints, extirpated the scapula, etc.; William Sands Cox (1802–76 one of the founders of the Birmingham School of Medicine in 182 author of *Memoir on amputation of the thigh at the hip-joint* (1845) Thomas Pridgen Teale (1801–68), founder of the Leeds School of Medicine, author of *A practical treatise on abdominal hernia* (1846; translated into German 1848, and into Dutch 1849), and best known by his work, *On amputation by a long and short rectangular flap* (1858) Joseph Jordan (1786–1873) of Manchester, the first provincial lecturer on anatomy and surgery whose certificates were recognized by the Royal College of Surgeons (in 1821), founder of the Lock Hospital in 181

and surgeon of the Manchester Infirmary after 1835; George Southam (1815–70) of Manchester, founder of the Chatham Street School of Medicine in 1850, surgeon to the Royal Infirmary in 1855, and professor of surgery in Owens College on its foundation in 1872, author of *Regional surgery* (3 parts, 1882–86); and Joseph Sampson Gamgee (1828–86), the son of a veterinary surgeon, who studied at University College, London, and after graduation studied at Paris, Pavia, and Florence. In 1857 Gamgee was appointed surgeon to the Queen's Hospital at Birmingham, which position he retained until 1881, becoming one of the most distinguished provincial surgeons of England. He was a brilliant operator and a fluent speaker. He urged the dry, infrequent dressing of wounds. His principal publications are—*On the advantages of the starched apparatus in the treatment of fractures and diseases of joints* (1853), *Researches in pathological anatomy and clinical surgery* (1856), *On the treatment of fractures of the limbs* (1871), and *On the treatment of wounds* (1878).

The leading Dublin surgeons during the century were Colles, Crampton, Carmichael, Porter, Cusack, Adams, Harrison, Bellingham, Smith, and Tufnell.

Abraham Colles (1773–1843) graduated at Edinburgh in 1797, and in 1804 became professor of surgery in Dublin, which position he held for thirty-two years, and for twenty years was the chief of the Irish surgeons. His name remains connected with the form of fracture of the carpal extremity of the radius described by him in the *Edinb. Med. and Surg. Journal* (1814), and with the so-called "Colles' law"—*i. e.* that a mother infected with syphilis through the fœtus acquires a certain degree of immunity and will not suffer by suckling the infant. In 1816 he first tied the subclavian within the scaleni. His principal surgical publications are a treatise on surgical anatomy (1811) and *Lectures on the theory and practice of surgery* (2 vols., 1844–45).

Sir Philip Crampton (1777–1858), a native of Dublin, was appointed surgeon to the Meath Hospital when twenty-one years old, and was one of the founders of the first private school for anatomy and surgery in Dublin. He was a skilful operator and an eloquent lecturer, and contributed numerous papers to medical journals.

Richard Carmichael (1779–1849), a native of Dublin, but of Scotch descent, passed his examination as assistant surgeon when seventeen years old, and in 1803 settled in Dublin and was appointed surgeon to St. George's Hospital. In 1826 he was one of the founders of the Richmond School of Medicine, giving lectures on surgery, and was very prominent in the various medical associations of his time. He bequeathed to the College of Surgeons in Ireland the sum of £3000, the interest of which was to be used in giving prizes every four years for the best essays on the state of the medical profession in Great Britain and Ireland, and these, known as the Carmichael prize essays, are valuable historical documents. His principal works relate to venereal diseases.

William Henry Porter (1790–1861), a pupil of Mr. Crampton, was elected surgeon to the Meath Hospital in 1819, and in 1836 succeeded Colles as professor of surgery in the Royal College of Surgeons. He was a bold operator, an eloquent lecturer, and an excellent teacher. Besides a number of important papers in the journals, he published

Observations on the surgical pathology of the larynx and trachea (1826 2d ed. 1837), a classical work.

James William Cusack (1787–1861), surgeon to Stevens's and Swift's hospitals, was in 1852 elected to the professorship of surgery in the University of Dublin, founded that year, and was three times president of the College of Surgeons. He was a bold and skilful operator, trained many pupils, and enjoyed the entire confidence of his professional brethren. He contributed some papers to periodicals, but wrote no special work.

Robert Adams (1791–1873), surgeon to the Jervis Street and the Richmond hospitals, was one of the founders of the Richmond (or, as it was afterward called, the Carmichael) School of Medicine, and in 1861 was appointed Regius professor of surgery in the University of Dublin. His principal work was his *Treatise on rheumatic gout, or chronic rheumatic arthritis of all the joints* (1857; 2d ed. 1873).

Robert Harrison (1796–1858), a native of Cumberland, was apprenticed to Colles in 1810, took the degree of M. B. in 1824, and was appointed professor of anatomy and surgery in the University of Dublin in 1837. His principal work was *The surgical anatomy of the arteries* (2 vols., 1824–25).

O'Bryen Bellingham (1805–57) graduated at Edinburgh in 1830, and was elected surgeon to St. Vincent's Hospital in 1835. His name is especially connected with the treatment of aneurism by compression, a method which was systematized and made popular by Dublin surgeons, and with regard to which his little book, *Observations on aneurysm, and its treatment by compression* (1847), is still a valuable work.

Robert William Smith (1807–73), a native of Dublin and an apprentice of Richard Carmichael, was a teacher of surgery in the Richmond Hospital School, and in 1849 was appointed the first professor of surgery in the School of Physic of the University of Dublin, the chairs of anatomy and surgery having been united prior to that date. He was eminent as a teacher and as a skilled pathologist, was for thirty-five years secretary of the Dublin Pathological Society, and made numerous and valuable contributions to surgical literature. His principal work was *A treatise on fractures in the vicinity of joints, and on certain forms of accidental and congenital dislocations* (1847).

Thomas Jolliffe Tufnell (1819–75), a native of Chippenham, Wilts, studied in London under Brodie and Cæsar Hawkins, entered the army medical service in 1841, and after the Crimean War retired from active service and settled in Dublin. He was surgeon to the City of Dublin Hospital and professor of military surgery in the school of the College of Surgeons. His principal works were—*Practical remarks on the treatment of aneurism by compression* (1851) and *The successful treatment of internal aneurism* (1864; 2d ed. 1875).

In addition to those already mentioned, and excluding those yet living, the following have been the prominent London surgeons since the middle of the century:

James Luke (1798–1881) studied at the London Hospital, where he became lecturer on anatomy in 1823, lecturer on surgery in 1825, and surgeon to the hospital in 1833, which position he resigned in 1861. His name is specially connected with a simplified method of operation for femoral hernia.

Frederic Carpenter Skey (1798–1872), a pupil of Abernethy, was for ten years lecturer on surgery in the Aldersgate School, and in 1843 became professor of anatomy at St. Bartholomew's Hospital, to which he had been elected assistant surgeon in 1827, and where he became surgeon in 1854, retiring in 1864. His principal work was his treatise on *Operative surgery* (1850; 2d ed. 1858).

John Hilton (1804–78) studied at Guy's Hospital, in the medical school of which he was appointed demonstrator of anatomy in 1828, and held this position for fourteen years, being reputed to be the best anatomist in London. In 1845 he was appointed assistant surgeon, and in 1849 surgeon, at Guy's. He is best known by his book on *Rest and pain* (1863; 2d. ed. 1877), one of the most valuable contributions of the century to surgical literature.

Edward Cock (1805–92), nephew and pupil of Astley Cooper, was appointed demonstrator of anatomy in Guy's Hospital medical school on its foundation in 1825, assistant surgeon to the hospital in 1838, and surgeon in 1848, retiring in 1871. He is best known by his papers on puncture of the bladder through the rectum (1852) and on a method of opening the urethra in cases of impermeable stricture (1866).

William Coulson (1802–77), a pupil of Tyrrell, studied in Berlin for two years, and on his return was associated with Tyrrell, Jones, Quain, Lawrence, and Wardrop in the medical school in Aldersgate street, in which he taught anatomy. At the same time he was on the editorial staff of *The Lancet*. In 1851 he was elected surgeon to St. Mary's Hospital. His principal works relate to diseases of the urinary organs.

Henry Hancock (1809–80) studied under Guthrie, became demonstrator of anatomy at the Westminster Hospital School in 1835, and in 1839 assistant surgeon at Charing Cross Hospital, where he succeeded to the lectureship of surgery on the death of Mr. Howship in 1841. His principal work was *On the operative surgery of the foot and ankle-joint* (1873).

Thomas Blizard (1811–88), a native of London and nephew of Sir William Blizard, became assistant surgeon to the London Hospital in 1833 and surgeon in 1849, from which position he retired in 1869. His principal publications were—*A Treatise on tetanus* (Jacksonian prize essay, 1836), *Practical treatise on the diseases of the testicle, spermatic cord, etc.* (London, 1843; 4th ed. 1878), and *Observations on the diseases of the rectum* (London, 1851; 4th ed. 1876). He contributed a number of very valuable papers to the *Medico-chirurgical Transactions*, including his "Improved observations on acute ulcerations of the duodenum in cases of burn" (1842).

Campbell de Morgan (1811–76), a younger brother of the mathematician, Augustus de Morgan, and a pupil of Sir Charles Bell, studied at University College, and in 1842 was elected assistant surgeon to the Middlesex Hospital, becoming full surgeon in 1848. In 1866–67 he became joint lecturer on surgery with Mr. Shaw. He contributed to Holmes's *System of surgery* and some papers to periodicals, and published *The origin of cancer considered with reference to the treatment of the disease* (1872).

John Gay (1813–85) studied in London, and in 1836 became surgeon to the newly-established Royal Free Hospital. In 1856 he was surgeon

to the Great Northern Hospital. His principal works are—*On femora rupture* (1848) and *On varicose veins* (1868). He must not be con founded with John Gay (1791–1870), a distinguished surgeon at Swindo and a pupil of Abernethy, who graduated in 1811, or with his son of th same name, who died at Swindon in 1869.

Robert Druitt (1814–83) was not connected with any hospital and di not practise surgery, but his *Vade Mecum*, the first edition of which ap peared in 1838 and contained the teachings of Green and of Josep Henry, met with great favor, reaching its eleventh edition in 1878 an a sale of forty thousand copies.

Richard Holmes Coote (1817–72), a pupil of Sir William Lawrenc became demonstrator of anatomy at St. Bartholomew's in 1846, assistan surgeon to the hospital in 1852, and surgeon and lecturer on surgery i 1863. He contributed many papers to journals and transactions, and best known by his treatise *On joint diseases*, published in 1867.

John Marshall (1818–91), a student and assistant of Liston, becam surgeon of University College Hospital and professor of surgery, i which position he gave special attention to physiology and patholog and to the views of Virchow, Cohnheim, and other German authoritie During the latter part of his life he was president of the General Medic Council. His principal published work was his *Outlines of physiolog* (2 vols., 1867).

Alfred Poland (1822–72), a pupil of Mr. Aston Key, became dem onstrator of anatomy at Guy's Hospital in 1845, assistant surgeon the hospital in 1849, and full surgeon in 1861. His *Essay on gunsh wounds and their treatment* received the Jacksonian prize at the Colle of Surgeons, and his paper, *The injuries and wounds of the abdome* gained for him the Fothergillian medal of the Medical Society of Lo don. He contributed many papers to *Guy's Hospital Reports* and al to the weekly medical journals, but wrote no important separate wor

John Cooper Forster (1823–86), the son of a medical man, studied Guy's, where in 1850 he was appointed demonstrator of anatomy, 1855 assistant surgeon, and in 1870 surgeon, which latter position resigned in 1880. He performed the first gastrostomy in England 1858. His only published separate work was on *The surgical disea of children* (1860).

George William Callender (1830–79) studied at St. Bartholomew where he became assistant surgeon in 1861, surgeon in 1871, and l turer on surgery in 1873. He contributed largely to *St. Bartholome Hospital Reports*, of which he was surgical editor from 1865 to 18 and also furnished many papers and notes of clinical lectures to journ and transactions. The *Transactions of the Royal Society* for 1869 c tain an important paper by him on "The formation and growth of bones of the human face." He was one of the first to carry out in det asepsis in surgery, as contradistinguished from antisepsis. His o separate work was *Anatomy of the parts concerned in femoral rupt* (1863).

Peter Charles Price (1832–64), the son of a physician, studied King's College, and became assistant to Mr. Fergusson in 1854. He appointed assistant surgeon to King's College Hospital in 1861. paid special attention to the pathology and surgery of the joints, and m

especially to the diseases of the knee and their treatment by excision. His principal work is *A Description of the diseased conditions of the knee-joint which require amputation of the limb, and those conditions which are favorable to excision of the joint, etc.*, published after his death in 1865.

Charles Frederick Maunder (1832–79) studied in Bristol, London, Edinburgh, and Paris, served in the army during the Crimean War, and was appointed assistant surgeon to the London Hospital in 1860, and surgeon in 1869. He was a bold and skilful operator, and his text-book on operative surgery (1860; 2d ed. 1873) was an excellent manual.

William Frederick Teevan (1833–87) was educated at University College, and was elected assistant surgeon of the West London Hospital for Urinary Diseases in 1866, after which he devoted himself more especially to the surgery of the genito-urinary organs. He is best known by his work, *Inquiry into the causation, diagnosis, and treatment of fractures of the internal table of the skull* (1864), which is a classical work of reference on this subject.

Marcus Beck (1843–93) studied at Glasgow under Mr. Joseph Lister, his cousin, and at University College, London, and in 1873 was appointed assistant surgeon to University College Hospital, becoming surgeon in 1885 and lecturer on surgery in the same year. He was one of the first to introduce antiseptic methods in surgery in London, and, though not a voluminous writer, made some valuable contributions to surgical literature, including a paper on "Consecutive nephritis," or surgical kidney, in Reynolds's *System of medicine*, and a part of the report on pyæmia and septicæmia in the *Transactions of the Pathological Society* for 1879.

Frederick LeGros Clark (1811–92), an apprentice of Travers, studied at St. Thomas's Hospital, beginning in 1827, and was appointed assistant demonstrator of anatomy in 1830. In 1839 he became lecturer on anatomy and physiology, in 1843 assistant surgeon to the hospital, and in 1853 full surgeon, which office he retained for twenty years. When Mr. South resigned the chair of surgery Mr. Clark succeeded him, and retained the office until he retired from the hospital in 1873. His principal work was his *Lectures on the principles of surgical diagnosis: especially in relation to shock and visceral lesions* (London, 1870; 2d ed. 1872). A number of his papers in journals and addresses were collected and printed under the title of *Papers on surgery, pathology, and allied subjects* (8vo, London, 1889).

The two greatest advances in surgery in the nineteenth century are the introduction of anæsthetics, which was due to American surgeons, and will be referred to hereafter, and the introduction of systematic and scientific antisepsis and asepsis in the treatment of wounds and the performance of surgical operations, which is due to an English surgeon, Sir Joseph Lister, who brought it into notice in 1867–68. Antiseptics of various kinds had been proposed and used by others prior to this date. Küchenmeister of Dresden had reported good results from the use of carbolic acid in 1860; Lemaire's work on carbolic acid appeared in 1863; Campbell de Morgan used chloride of zinc in 1866; but it was Mr. Lister who established the method on the basis of Pasteur's experiments showing that putrefaction is due to the action of micro-organisms, and who systematically sought for, and found, means to prevent the access of these micro-organisms to wounds or to destroy their

vitality if they had already gained admission, and to do this with the least possible injury to the living tissues. The actual cautery and the boiling oil of the surgeons of the fifteenth and prior centuries were antiseptic, no doubt, as were also some of the multifarious wound-dressings in use since the days of Hippocrates; but antiseptic surgery began with Mr. Lister, and its progress has been largely due to the scientific manner in which he developed and expounded it. With the introduction of Koch's method of cultures on solid or semi-solid media, which is the foundation of the new bacteriology, has come a knowledge of the mode of development and of the results of the growth of some of these organisms which has already revolutionized operative surgery, and made obsolete and comparatively useless a vast amount of surgical literature and statistics. An illustration of this is given in a comparison of the results obtained by Liston in 1844 with those obtained in the University College Hospital forty years later, contained in an address on surgery by John Marshall in the *British Medical Journal* (August 8, 1885, p. 235). He concludes that "injuries not involving a breach of the surface of the body, simple inflammations consecutive to these, or so-called idiopathic local inflammations which come under the care of the surgeon, such as sprains, simple dislocations, synovitis, orchitis, and other cases, were not less satisfactorily treated in 1844–45 than in 1883, and the progress of the patients toward recovery was quite as rapid, but that in cases of wounds and operations the difference in favor of the latter period is very striking."

After the abolition of the medical faculties and societies in France by the decrees of 1792 and 1793 the evil results of want of means for giving proper medical instruction soon became evident from the fact that properly-qualified medical officers could not be found to supply the places of those who died in the service of the armies of the Republic. By direction of the National Convention a report was prepared by the celebrated chemist, Fourcroy, on the best plan of organizing medical schools to meet this want, and in accordance with this report a law was passed in 1794 establishing medical schools at Paris, Montpellier, and Strasburg. The method taken to secure students was peculiar and effectual. From each district in France a young man between seventeen and twenty-six years of age, whose name had not been drawn in the first conscription, was selected by the governmental authorities and forwarded at the expense of the State to one of these schools, three hundred being assigned to Paris, one hundred and fifty to Montpellier, and one hundred to Strasburg. Three years was the period of instruction allowed, and as soon as they were considered qualified they were sent to join the troops. These were really military medical schools analogous to that established at Berlin. They did not confer the doctor's degree, the object being simply to manufacture medical officers as soon as possible.

After several changes the Paris school was definitely organized in 1804, and became a medical society as well as a teaching body, the object of the government being to obtain not only a medical faculty, but a scientific body which should be capable of giving advice to the government. The society part of this arrangement was dissolved in 1821 by the formation of the Academy of Medicine.

In 1806 the Imperial University was created, and in 1808 the med-

ical school became its faculty of medicine. In 1822, owing to political troubles, the Faculty of Medicine was suppressed, but it was re-established in 1823 with a change in a number of the professors, A. Dubois and Pelletan losing their chairs.

In 1830 the Faculty of Medicine was again reorganized, the acts of 1822 and 1823 being abolished and the old professors being again placed in their chairs, while at the same time the concours was again established as a means of filling the professorships. Jules Rochard, in his *Histoire de la chirurgie française au xix^e^ siècle* (Paris, 1875), gives the most complete and satisfactory account of French surgery of the century, and his division of it into four periods will be followed in this sketch.

At the beginning of the century the leading surgeons in Paris were Sabatier, Deschamps, Lassus, Boyer, Dubois, Pelletan, and Lallement. Sabatier and Deschamps have already been referred to in speaking of French surgeons in the latter part of the eighteenth century.

Pierre Lassus (1741–1807), professor of surgery in the École de Santé and consulting surgeon of Napoleon I., was a learned surgeon who was the author of a good history of anatomy, of a manual of operative surgery (2 vols., Paris, 1794), and of *Pathologie chirurgicale* (2 vols., Paris, 1805–06).

Alexis Boyer (1757–1833) was a pupil of Desault and surgeon of the Charité, a modest, quiet, studious, hard-working man, without much originality or brilliancy either in his clinical work or his lectures and writings, but a careful compiler and a thoroughly reliable teacher. His *Traité des maladies chirurgicales* (11 vols., 1814–26) is a practical system of surgery, the most complete of its kind then in existence, and for many years it remained the highest authority in this branch of medical literature. His chief contributions to practical surgery were his descriptions of the painful crepitation of tendons, of translucency of the tumor as diagnostic in hydrocele, of bleeding fungous tumors, and of the complications of fissure of the anus. His system is characterized by Malgaigne as a summary of the works and opinions of the French Academy of Surgery, which is no doubt correct. It is a résumé of French surgery which he gives, and he has little or nothing to say of the surgery of Germany, of England, or of America.

Antoine Dubois (1756–1837), a pupil of Desault, professor of anatomy in the École de Santé, was a skilful surgeon and a good clinical teacher, but wrote nothing of importance.

Philippe Jean Pelletan (1747–1829), a pupil of Louis and of Sabatier, succeeded Desault as chief surgeon at the Hôtel Dieu, became professor of clinical surgery at the founding of the Medical Faculty of Paris, and consulting surgeon to the emperor. In 1815 he was professor of operative surgery, and retired from practice in 1823. He was an eloquent lecturer, but made no valuable contributions to the art. His *Clinique chirurgicale* (3 vols.) was published in 1810–11.

André Marie Lallement (1750–1830), a pupil of Desault, was surgeon to the Salpêtrière and professor of surgery in the Medical Faculty. He wrote only a few papers for periodicals.

To these should be added the names of Larrey, Percy, Dufouart, and Saucerotte.

Dominique Jean Larrey (1766–1842), the most distinguished military surgeon at the end of the last and the beginning of the present century, served in the Napoleonic campaigns, and was professor in the military school founded in 1796 at Val-de-Grâce. His chief writings are his *Mémoires de médecine militaire et campagnes* (4 vols., Paris, 1812–17) and his *Recueil de mémoires de chirurgie* (Paris, 1821).

Pierre François Percy (1754–1825) was professor in the military medical school in 1820. At his suggestion a battalion of litter-bearers, or a hospital corps, was created in the Italian war.

To the second period (1814–35) belong Dupuytren, Richerand, Roux, Marjolin, Lisfranc, Sanson, and Jules Cloquet.

Guillaume Dupuytren (1778–1835) at the age of eighteen obtained by concours a position as prosector in the Academy, in 1801 became chief of the department, in 1808 obtained a place on the surgical staff of the Hôtel Dieu, in 1812 was appointed to the chair of operative surgery, and in 1815 became surgeon-in-chief to the Hôtel Dieu. For the next fifteen years he was the most distinguished surgeon in France—and, for that matter, in the world, as the fame of his clinical teaching drew crowds of students from all countries. His studies in pathological anatomy and in experimental physiology contributed greatly to his success, which turned largely on his unequalled powers of diagnosis.

He was not a student of books, and wrote but little, and that little is not remarkable. He made no great discoveries, his chief contributions to the art being his method of treating artificial anus by means of his compressing enterotome, his excisions of the jaws, and the subcutaneous section of the sterno-mastoid. He was a cold, reserved, unscrupulous, and ambitious man, with contemptuous and offensive manners, who can hardly be said to have had any personal friends; but he was an incessant worker, thoroughly self-reliant, a bold operator, and unsurpassed as a clinical teacher in the precision, method, and clearness with which he stated all the salient points of the case on hand. His clinical lectures were noted and published by Brierre de Boismont and Buet in 1832–34 in 4 volumes; a second edition, in 6 volumes, appeared in 1839. Those portions of these lectures which relate to injuries and diseases of the bones were translated by F. Le Gros Clark and published by the Sydenham Society in 1847; and other selections, under the title of *On lesions of the vascular system, diseases of the rectum, etc.*, by the same translator, form a volume of the Sydenham Society's publications issued in 1854.

Balthasar Anthelme Richerand (1779–1840) published his *Nosographie chirurgicale* (1805–06, 3 vols.; 5th ed. in 1821, 4 vols.). He was appointed professor of surgical pathology in the faculty by Napoleon in 1807. He was more successful as a writer than he was as an operator or teacher, but he had nothing of the impartial spirit of the true critic, and the man whom he praised one year he would denounce the next. He made no special contributions to surgery with the exception of a case of resection of the fifth and sixth ribs on the left side, being the first instance in which such an operation had been performed to this extent.

Philibert Joseph Roux (1780–1854) was a student and warm personal friend of Bichat, whom he succeeded as a teacher. He became surgeon at the Charité in 1810, professor of surgery in the faculty in 1820, and succeeded Dupuytren at the Hôtel Dieu in 1835. He first became cele-

brated by the publication, in 1815, of his *Relation d'un voyage fait à Londres en 1814; ou parallèle de la chirurgie angloise avec la chirurgie françoise*—a book which had considerable influence in diffusing in each country a knowledge of what had been done in the other, in spite of the crude and superficial views on many points which it presented. His most important contributions to the art were in plastic surgery, particularly in staphylorrhaphy, which he first performed in 1819, and in suture of the ruptured perineum, which he first performed in 1832. He gave the first distinct course of lectures on surgical anatomy in 1812. His most important literary work was his *Quarante années de pratique chirurgicale*, of which but two volumes were published, the first, relating to plastic surgery, appearing in 1854, and the second, on diseases of the arteries, in 1855.

Jean Nicolas Marjolin (1780–1850) was prosector of anatomy in 1806, and in 1816 became second surgeon of the Hôtel Dieu, but soon retired to avoid unpleasant association with Dupuytren. In 1819 he became professor of surgical pathology. He was a good surgeon and extremely popular as a teacher, but was not distinguished as an operator. His name remains connected with the form of malignant degeneration of chronic ulcer of the leg known as the "warty ulcer of Marjolin."

Jacques Lisfranc (1790–1847) studied at Lyons and Paris and graduated in 1813, after which he served for a short time in the army and then settled in Paris. In 1825 he became second surgeon at La Pitié, and a short time afterward, on the death of Béclard, he became the chief surgeon at this hospital. He sought to reduce operative surgery to mathematical rules, and his name is connected with methods of partial amputation of the foot, of amputation at the wrist, the shoulder-joint, and the hip, and with methods of resection of the head of the humerus, for removal of the lower jaw, for excision of the rectum, and for amputation of the neck of the uterus. He was an excellent operator and clinical teacher, but envious of the greater success of some of his contemporaries, particularly Dupuytren and Velpeau, and died dissatisfied with himself and with every one around him. His principal publications are—*Clinique chirurgicale de l'hôpital de la Pitié* (3 vols. 8vo, Paris, 1841–43) and *Précis de médecine opératoire* (3 vols. 8vo, Paris, 1845–48).

Louis Joseph Sanson (1790–1841) was a pupil and friend of Dupuytren. After serving in the army from 1812 to 1815, he returned to Paris, and in 1825 became the second surgeon of the Hôtel Dieu. In 1836 he succeeded Dupuytren as professor of clinical surgery, winning the place by concours. The first forty years of his life were a continued struggle with poverty, and his subordination to Dupuytren prevented him from obtaining the reputation to which his skill as a diagnostician and operator entitled him. His principal work was the *Nouveaux éléments de pathologie médico-chirurgicale, par Roche et Sanson* (4 vols., 1824; 3d ed. 1833), of which he wrote all the surgical part.

Jules Germain Cloquet (1790–1883) came to Paris in 1810 and became preparer for the museum of the School of Medicine. He published a valuable series of anatomical observations on hernia in 1817, and a magnificent work on human anatomy, containing a large number of plates, which is still classic; in 1831 he became professor of surgical pathology, and succeeded Dubois in the chair of clinical surgery in 1833, which

position he retained until 1850. He contributed a large number of papers on anatomical and surgical subjects to the journals, and devised a number of new instruments.

Joseph Souberbielle (1754–1846) studied at Paris under Desault and entered the army. He took his degree in 1813, after which he remained in Paris, devoting himself chiefly to lithotomy, and especially to the suprapubic method. He was a relative of Frère Côme and of his nephew Baseilhac, and inherited their instruments and reputation. He is said to have performed the suprapubic operation over twelve hundred times.

To this period belongs the introduction of lithotrity, with which are especially connected the names of Civiale, Leroy (d'Étiolles), and Heurteloup.

Jean Civiale (1792–1867) studied at Paris, graduating in 1820, and made a specialty of the diseases of the urinary organs, and especially of lithotrity, which he successfully performed on a living human subject in January, 1824. In 1828 a special section for those afflicted with calculus was set apart for him in the Hospital Necker, and his practice became enormous. He had much mechanical ingenuity and dexterity, but he was neither a speaker nor a writer, and the greater part of the numerous publications which appeared under his name were really written by Jourdan, Boisseau, Bégin, and others. In his first book, *Nouvelles considérations sur la rêtention d'urine, etc.* (1823, p. 115), he referred to a report of Pouteau that "haricots blancs" had passed from the stomach into the urinary bladder, etc., and said: "Si les faits rapportés sont exacts, ces corps suivent-ils le torrent de la circulation?" Some kind friend pointed out the blunder to him before the edition was put on the market, and he cancelled the greater part, but a few had been sent out as presentation copies, and these are now regarded as curiosities in medical literature.

Jean Jacques Joseph Leroy (d'Étiolles) (1798–1860) studied at Paris, graduating in 1824, prior to which he had devised a three-pronged instrument for seizing and perforating a stone in the bladder, and his whole life was mainly devoted to this branch of surgery and to bitter contests as to priority of invention. He was not, however, a pure specialist, and was a much more scientific man than Civiale. The list of his publications is a long one, but they are comparatively brief papers.

Charles Louis Stanislaus Heurteloup (1793–1864), son of Baron Nicolas Heurteloup, a distinguished French army surgeon, studied in Paris, graduating in 1823, and almost immediately turned his attention to the subject of lithotripsy and to criticism of the work of Civiale and Leroy (d'Étiolles). He greatly improved the instruments used in lithotripsy, and is said to have spent one hundred and fifty thousand francs in perfecting his inventions. From 1828 to 1832 he was in London, and published there his *Principles of Lithotrity* (1831).

To this period also belong Delpech and Lallemand of Montpellier.

Jacques Mathieu Delpech (1777–1832), a native of Toulouse, graduated at Montpellier in 1801, after which he studied in Paris. In 1812 he obtained, by concours, the chair of surgery at Montpellier, and soon became celebrated as an operator and as a clinical teacher. In the height

of his fame he was assassinated by a patient whom he had treated for some disease of the genitals. His principal contributions to surgery relate to hospital gangrene and to orthopædia. He first pointed out that tubercular disease of the vertebræ was the frequent origin of Pott's disease of the spine, insisted on the importance of the fibrous tissues in connection with deformities, and in 1816 performed subcutaneous section of the tendo Achillis with the avowed intention of thus excluding the air and obtaining union by first intention. The successor of Delpech in the chair of clinical surgery was Michel Serre (1799–1849), who graduated at Montpellier in 1825, and who published his *Traité de la réunion immédiate, etc.*, in 1830, and his *Traité sur l'art de restaurer les difformités de la face, etc.*, in 1842.

Claude François Lallemand (1790–1853), a native of Metz, studied at the Military Medical School of that place, and at the age of thirteen entered the army medical service. In 1811 he went to Paris and became an assistant to Dupuytren; in 1819 he was appointed professor of clinical surgery at Montpellier; and after the death of Delpech he was the chief surgeon in the south of France. In 1823 he lost his place for ten months through clerical intrigues, but was replaced by the Council of Public Instruction. He is best known as the author of *Des pertes séminales involontaires* (3 vols., 1836–42), of which several English translations were published. He devised the method of autoplasty by bending without twisting the flap, and the method of treating erectile tumors by the insertion of needles.

In the third period (1835–47) come Gerdy, Velpeau, Blandin, A. Bérard, Laugier, Jobert, Amussat, and Vidal.

Pierre Nicolas Gerdy (1797–1856) studied in Paris under the most adverse circumstances of poverty and sickness, and in 1828 became second surgeon to La Pitié, where he was under the orders of Lisfranc, who gave him very few opportunities. In 1831 the surgeons of the hospitals were placed on an equal footing, the position of surgeon-in-chief being abolished. In 1833, as the result of an intrigue of Dupuytren to suppress Velpeau, Gerdy became professor of the principles of surgery in the faculty, and in 1839 was appointed surgeon to La Charité, taking the place of Guerbois. The list of Gerdy's works is a long one, but he was a physiologist rather than a surgeon, and his most important surgical publication was his *Traité des bandages et des pansements* (2 vols., 1837–39).

Alfred Armand Louis Marie Velpeau (1795–1867), the son of a blacksmith, whose trade he learned, studied at Tours, where he received the diploma of *officier de santé*, and in 1820 came to Paris, and soon became assistant preparer for Cloquet. He graduated in 1823, and published his *Traité d'anatomie chirurgicale*, the first complete and systematic work in which the details of regional anatomy were throughout considered with reference to their surgical relations. In 1828 he became surgeon to the Hospital St. Antoine, and in 1830 to La Pitié, where he remained until 1834, when he was elected to the chair of clinical surgery in the faculty left vacant by the death of Boyer. In 1832 he published his *Nouveaux éléments de médecine opératoire* (3 vols. and atlas), the largest and most complete work on this subject which had yet appeared. The English translation of this by Townsend, with notes

of Valentine Mott (New York, 1847), and especially the latest edition, with additions by G. C. Blackman (New York, 1856, 3 vols. and atlas), is a great storehouse of historical data relating to the principal operations of surgery up to that date. In 1854 he published his *Traité des maladies du sein*, a large book, characterized by Trélat as the most original, personal, and probably the most durable of his works, and which must not be confounded with his *Petit traité des maladies du sein*, published in 1838 as a reprint of his article in the *Dictionnaire de médecine*, and which was translated into English by Parkman in 1840. He made no great discoveries or improvements, yet he contributed greatly to the progress of surgery between 1825 and 1855, and especially in surgical anatomy, the pathology of pyæmia, the diagnosis of tumors, and the diseases of the breast. A man of strong common sense, an indefatigable worker, a conscientious and conservative critic, an excellent teacher and operator, his lessons were followed by crowds of pupils, including many who became distinguished surgeons in other countries as well as in France.

Philipp Fréderic Blandin (1798–1849) graduated at Paris in 1824, in 1828 became a surgeon to the Hospital Beaujon under Marjolin, and in 1841 succeeded Richerand in the chair of operative surgery. He also became surgeon to the Hôtel Dieu. Blandin was not a great surgeon nor a great teacher, and there is little in his writings which is of interest at the present day, but he was a sensible, practical, honest man who did good work in his time.

Auguste Bérard (1802–46) studied at Paris, graduating in 1829, became a surgeon of the Central Bureau by concours in 1831, and, subsequently, surgeon to the hospitals St. Antoine, Salpêtrière, Necker, and La Pitié, and in 1842 succeeded Sanson as professor of clinical surgery in the faculty. The student part of his life was one of great poverty, shared by his brother, P. Bérard, who devoted himself to physiology. A. Bérard wrote some excellent concours theses, many articles in the *Dictionnaire de médecine*, and began, with Denonvilliers, a *Compendium de chirurgie pratique*, of which only a portion was issued at his death. His contributions to surgery relate to the treatment of fractures, continuous irrigation of wounds, erectile tumors and varices, staphylorrhaphy, etc. He was a skilful operator and an excellent teacher.

Stanislaus Laugier (1799–1872), a pupil of Dupuytren, graduated at Paris in 1828, became surgeon to the Hospital Necker in 1832, to the Hospital Beaujon in 1836, professor of clinical surgery in the faculty in 1848, and surgeon to the Hôtel Dieu in 1854, succeeding Roux. He first called attention to the discharge of serous fluid from the ear in certain fractures of the skull, and was the first to propose suture of divided nerves. He was a prudent, quiet, conservative surgeon and a good teacher, but he wrote little and his name is now almost forgotten.

Antoine Joseph Jobert (1799–1867) studied at Paris, graduated in 1828, was appointed a surgeon of the Central Bureau by concours in 1829, and surgeon to the Hospital St. Louis in 1831. In 1853 he became surgeon to the Hôtel Dieu, and in 1854 succeeded Roux as professor in the faculty. His childhood and student-life were spent in great poverty, at times in actual destitution; his subsequent life was a very unhappy one, in spite of the honors and wealth to which he attained;

he became gloomy and eccentric, and ended his days in an asylum for the insane. Lacking in preliminary education and in oratorical gifts, his success was due to the novelty and importance of his contributions to plastic surgery and to the surgery of the female organs of generation. He was a better writer than speaker, and wrote much; his *Mémoire sur les plaies du canal intestinal*, published in 1826, before his graduation, was based upon the experimental method of Hunter, and demonstrated the importance of producing union between the serous surfaces. His most important works were—*Traité de chirurgie plastique* (2 vols. and atlas, 1849), *Traité des fistules vésico-utérines, etc.* (1852), and *De la réunion en chirurgie* (1864).

Jean Zulema Amussat (1796–1856), the son of a country physician, entered the army medical service in 1814, after which he studied at Paris, graduating in 1826. He did not become a professor in the faculty or surgeon to a great hospital, but he commenced private teaching even before he graduated, and he communicated most of his discoveries to the Academy of Medicine, which granted him prizes for his contributions on lithotrity, on the torsion of arteries, on the entrance of air into the veins, on lumbar colotomy, etc. He wrote much, but his papers were never collected.

Auguste Théodor Vidal (de Cassis) (1803–56) studied at Marseilles and Paris, graduating in 1828, soon after which he became connected with the newly-founded *Gazette des hôpitaux*. He never became a professor or connected with a great surgical clinic, and, being a sarcastic journalist and rather bitter critic, he made few friends. His reputation as a surgeon rests upon his *Traité de pathologie externe* (5 vols., 1838–41), which was a popular manual and reached a fifth edition in 1860. He invented serres-fines, was the first to inject a solution of nitrate of silver into the uterine cavity, and contributed largely to our knowledge of syphilis, successfully opposing Ricord, the great authority of the day, in some important points relating to this disease.

Joseph Gensoul (1797–1858) studied at Lyons and Paris, graduating in 1824, and in 1826 became chief surgeon of the Hôtel Dieu of Lyons, where he soon acquired celebrity as a bold and skilful operator. He first (in 1826) excised the entire upper jaw, in 1827 he removed the parotid gland, and, first in France, excised half of the lower jaw, and he first treated varices with caustic. He wrote very little, his chief publication being his *Lettre chirurgicale sur quelques maladies graves du sinus maxillaire et de l'os maxillaire inférieur* (1833).

Amédée Bonnet (1802–58) studied at Paris, where he graduated in 1832, and in 1833 obtained the position of surgeon to the Hôtel Dieu at Lyons by concours, after which he became a professor in the school, and was soon celebrated as a teacher. His principal publications are—*Traité des sections tendineuses et musculaires dans la strabisme, la myopie, etc.* (1841), *Traité des maladies des articulations* (2 vols., 1845), and *Traité de thérapeutique des maladies articulaires* (1853), which latter remain as valuable contributions to the surgery of the joints.

Charles Gabriel Pravaz (1791–1853) studied at Paris, graduated in 1824, and devoted himself to orthopædic surgery, associating himself with Jules Guérin in a private orthopædic hospital. In 1835 he settled in Lyons. His principal contributions to surgery relate to orthopædia

—which he was one of the first to place on a scientific foundation—to the use of perchloride of iron, to the use of fine hollow needles for the injection of varices or erectile tumors, etc.

Raoul Henri Joseph Scoutettin (1799–1871), a native of Lille, entered the army, and graduated at Paris in 1822. He became one of the most distinguished of French military surgeons, was professor in the school at Metz in 1836, and in 1840 held the same position in the military hospital at Strasburg. In 1854 he was in charge of the military hospital in Constantinople and Pera, after which he returned to Metz, and was in charge of the military hospital until his death. He was a voluminous writer on matters connected with military medicine and surgery, and an excellent operator. He successfully performed tracheotomy on his infant daughter six weeks old.

Jean Baptiste Lucien Baudens (1804–57) studied in Paris, entered the army medical service in 1823, and graduated in 1829. He served in Africa from 1830 to 1837, in 1838 became professor in the hospital at Lille, and in 1842 professor at Val de Grâce. He was a distinguished military officer, and made numerous contributions to military surgery, among which may be mentioned his *Clinique des plaies d'armes à feu* (1836) and his *La guerre de Crimée, les campements, les abris, les ambulances, les hôpitaux, etc.*, first published in the *Revue des deux mondes* in 1857, and in separate form in 1858.

Jean Gaspard Blaise Goyrand (1803–66) studied at Paris, graduated in 1828, and, returning to his native city Aix, became chief surgeon to the hospital, and one of the most distinguished of the French provincial surgeons of his day. He made important contributions to the literature of amputations, fractures of the lower end of the radius, operations for loose bodies in the joints, extirpation of the tongue, urethral fistula, etc. His principal work is his *Clinique chirurgicale ; mémoires et observations de chirurgie, etc.* (Paris, 1870), published after his death by Dr. Silbert.

Jules Roux (1807–77), a native of Aix, studied at Toulon, entered the naval medical service in 1828, and became professor in the school of Toulon in 1842. He was distinguished as an operator and clinical teacher, devised a useful modification for disarticulation of the foot, made improvements in the operation of trephining, and was the first to make use of iodine injections in disease of the shoulder-joint. He made numerous contributions to the journals and learned societies, but published no important separate work.

To the fourth period (from 1847 to the present time) belong, in addition to those already referred to and those who are still living and do not yet belong to history, a number of well-known surgeons, of whom the most prominent at Paris were Malgaigne, Nélaton, Denonvilliers, Chassaignac, Richet, Follin, Broca, Dolbeau, Gosselin, and Trélat.

Joseph François Malgaigne (1806–65), a native of the Vosges, son of an *officier de santé*, studied at Paris, graduating in 1831, and after a short term of military service in Poland settled in Paris, where he became surgeon of the Central Bureau in 1835, and began to teach surgical anatomy. He was successively surgeon to the Hospital St. Louis and to La Charité, and in 1850 won by concours the chair of operative surgery vacated by Blandin.

Malgaigne was the greatest surgical historian and critic which the world has yet seen, a brilliant speaker and writer, whose native genius, joined to incessant labor, brought about a new mode of judging of the merits of surgical procedures—the mode of statistical comparison joined to experiment. He was not a great operator, and although he made some improvement in the art, such as his hooks for the treatment of fractures of the patella, his suggestion of suprathyroid laryngotomy, etc., these are of small importance as compared with his work of exploding errors, exposing fallacies in reasoning, and bringing to bear upon the work of the present day the light of the experience of the past, of which his treatise on fractures and dislocations affords many excellent examples. The reports of his speeches in the Bulletins of the Academy of Medicine are among the most delightful reading in surgical literature.

Auguste Nélaton (1807–73), the son of a French soldier, a native of Paris, studied at the Hôtel Dieu under Dupuytren and at the Foundling Hospital, graduating in 1836. He became professor of clinical surgery in 1851, was for many years a colleague of Malgaigne at the Hospital St. Louis, and for the last fifteen years of his life was the most popular surgeon in Paris. He was, in fact, in many respects, the best surgeon whom France has produced during the century, being unsurpassed as a diagnostician, as an operator, and as a clinical teacher, and was a modest, quiet gentleman who attacked no one and befriended many. He made many improvements in surgical technique, among which was the porcelain-headed probe which he devised for demonstrating the presence of the bullet in Garibaldi's ankle-joint. He brought into French practice the principle, so strongly insisted on by Guthrie, of ligating both ends of a wounded artery within the wound for either primary or secondary hemorrhage, improved the methods of treatment of nasopharyngeal tumors, first clearly demonstrated retro-uterine hæmatocele, and brought ovariotomy into good repute in France. He wrote comparatively little, his chief publication being his *Éléments de pathologie chirurgicale* (5 vols., 1844–59, of which the last two volumes were published by A. Jamain). The only publication of his clinical lectures is that made in 1855 by Dr. W. F. Atlee of Philadelphia from his own notes—a book which is not nearly as well known as it deserves to be.

Charles Pierre Denonvilliers (1808–72) studied at Paris and graduated in 1837; became a surgeon of the Central Bureau in 1840, in 1842 chief of the School of Practical Anatomy and surgeon of the Hôtel Dieu, and in 1856 professor of surgery. He was, however, more of an anatomist than a surgeon, although he was a good operator, especially in the field of plastic surgery. His most important services to medicine were rendered in his capacity as inspector-general of public instruction for medicine, to which he was appointed in 1858.

Édouard Pierre Marie Chassaignac (1804–79) studied at Nantes and Paris, graduating in 1835, and gave private courses in anatomy and operative surgery, but did not become a professor in the faculty, although he often competed for this position. He became surgeon to the Lariboisière in 1852. His most important contributions to surgery were the introduction of the method of the drainage of wounds and abscesses, his method of dressing wounds by complete occlusion, and his invention of the écraseur.

Louis Alfred Richet (1816–91), a native of Dijon, studied in Paris, graduating in 1844. He was surgeon to the hospitals Lourcine, St. Antoine, and La Pitié, and in 1864 became professor of clinical surgery in the faculty. His principal work was his *Traité pratique d'anatomie médico-chirurgicale* (Paris, 1857; 4th ed. 1873).

Eugène Follin (1823–67), a pupil of Velpeau, was a skilled anatomist and excelled in diagnosis. He introduced the use of the ophthalmoscope in France. His early death left his *Traité élémentaire de pathologie externe* unfinished, but it was continued and completed in six volumes by Duplay, and is a work of much practical value. His contributions to surgery are characterized by freedom from exaggeration and by sound sense.

Paul Broca (1824–80), the son of an army surgeon, studied at Paris, graduating in 1849, immediately after which he became prosector at the École pratique. In 1853 he became assistant professor in the faculty, and in 1867 professor of surgery, soon after which he exchanged this chair for that of clinical surgery. He was successively surgeon to the hospitals St. Antoine, La Pitié, Des Cliniques, and Necker. He was an original investigator of a high order, as is shown by his researches on cerebral localization, aphasia, etc. Distinguished as an anatomist, a pathologist, and a surgeon, he devoted himself in the latter part of his life more especially to anthropology, of which he may almost be said to have been the founder in France. He was the first to trephine for an abscess of the brain, the location of which was determined by his study in the localization of function of that organ. In fact, his studies may be said to be the foundation of modern brain-surgery.

Henri Ferdinand Dolbeau (1830–77) studied at Paris, graduating in 1856, became hospital surgeon in 1858, serving successively at the Hospital for Children, Necker, and the Hôtel Dieu, where he replaced Jobert in 1865, and in 1868 became professor in the faculty. He contributed to our knowledge of club-foot, of cartilaginous tumors, of epispadias, and of spina bifida, suggested lithotrity through perineal section in cases of large calculus, and was an excellent practical teacher. His principal works are *De l'épispadias* (1861), *Traité pratique de la pierre dans la vessie* (1864), and *Leçons de clinique chirurgicale* (1867).

Athanase Léon Gosselin (1815–87), a native of Paris, graduated in 1843, and became surgeon to the hospitals, and in 1858 professor of surgery in the faculty, and surgeon to La Charité in 1867. He contributed to journals many valuable papers which were collected and published in his *Clinique chirurgicale de l'hôpital de la Charité* (2 vols., 1873; 3d. ed. 1879, and translated into English, Philadelphia, 1878).

Ulysse Trélat (1828–90), the son of a physician, and a native of Paris, studied at Paris, graduating in 1854. He became prosector in 1856, in 1857 assistant professor in surgery to the faculty, and in 1860 surgeon of the Central Bureau, serving successively at the hospitals Maternité, St. Antoine, St. Louis, La Pitié, and La Charité. He became professor of surgical pathology in the faculty in 1872. He was an eloquent speaker and fond of speaking, a very popular clinical teacher, and the first in France to recognize the importance of the new antiseptic method. His publications were mainly in journals and transactions; they relate chiefly to plastic surgery of the palate and of the face, to hernia, tuber-

culosis of the tongue, œsophagotomy, etc. His *Leçons de clinique chirurgicale* appeared in 1877, and his *Clinique chirurgicale* (2 vols.) in 1891.

In addition to these may be mentioned the following:

Joseph Pierre Eléonor Pétrequin (1809–76) studied at Paris, graduating in 1835, in 1838 became an assistant surgeon in the Hôtel Dieu at Lyons, and in 1855 became professor of surgery in the school. He was a learned historian in matters pertaining to the art, a skilled physician as well as surgeon, and a voluminous writer. His principal publications are—*Traité d'anatomie médico-chirurgicale et topographique* (1844; 2d ed. 1857, translated into German, 1845), *Clinique chirurgicale de l'Hôtel Dieu de Lyon* (1850), *Mélanges de chirurgie et de médecine* (1870, 1873, 1877), and *Chirurgie d'Hippocrate* (2 vols., 1878).

Joachim Albin Cardozo Cazado Giraldès (1807–75), a native of Portugal, studied at Paris and graduated in 1836. In 1848 he became a surgeon of the Central Bureau, and was appointed to the Children's Hospital. The results of his work in this hospital appear in his *Leçons cliniques sur les maladies chirurgicales des enfants, etc.* (1869).

Charles Emmanuel Sédillot (1804–83), a native of Paris, studied under Boyer and Roux, and in 1824 at the Val de Grâce. He graduated in 1829, after which he entered the military service, and in 1836 became professor of operative surgery at Val de Grâce. In 1841 he became professor of surgery at Strasburg by concours, succeeding Bégin. He made many valuable contributions to surgery, relating, among other things, to dislocations, plastic operations, urethrotomy, pyæmia, the surgery of the bones, gastrotomy—to which he gave the name—operations for cancer of the tongue, etc. In 1840 he performed the first successful amputation at the hip-joint in Paris.

Paul Louis Benoît Guersant (1800–70), son of a celebrated Paris physician, studied at Paris, graduated in 1828, and in 1833 became surgeon to the Children's Hospital by concours, remaining in this position until 1860. His principal work is his *Notices sur la chirurgie des enfants* (1864–67; translated into English, 1873).

Jules Réné Guérin (1801–86), a native of Boussu (at present in Belgium), studied at Paris, being a pupil of Boyer and Roux, and graduated in 1826. In 1830 he founded the *Gazette médicale de Paris*, of which he was the editor for forty years. He devoted himself to orthopædic surgery, having established a private orthopædic hospital, and in 1838 published his first memoir on deformities of the osseous system, which was followed by a long series of similar papers. A portion of these have been collected and published under the title *Œuvres du docteur Jules Guérin, etc.* (Paris, 1882), said to have been intended to fill 16 volumes, with 100 plates, but which has never been finished. As a controversialist and journalist he was better known and better liked among non-professional persons than among those of his own profession.

Félix Adolphe Richard (1822–72) studied at Paris, and graduated in 1848. He became surgeon of the Central Bureau in 1852, and assisted Nélaton in his clinical teaching. His principal work is his *Pratique journalière de la chirurgie* (1868).

When the Austrian Netherlands became a part of the French Re-

public, in 1795, the five medical schools in Belgium were suppressed, as those in France had been, and with much the same results. Each large town attempted to regulate the matter by local examinations and by the establishment of schools of an inferior class, mainly devoted to giving instruction in surgery and obstetrics to uneducated men. When the kingdom of the Netherlands was created in 1815 the Universities of Ghent and Liège were established and the old University of Louvain was rehabilitated. In organizing these schools a strong German element was introduced, and it was ordered that the lectures should be given in Latin. The result was a failure, for Paris was the great medical school of the day, and the Belgian students went there. The Revolution of 1830 closed the universities, and in 1835 medical teaching was placed substantially on the French basis.

The leading surgeons of Holland in this century have been Hendriksz, Onsenoort, Tilanus, and Ranke.

Pieter Hendriksz (1779–1845) served in the army, studied at Gröningen, where he began to teach surgery in the hospital in 1810, in 1827 was called to Leyden, and in 1828 to Amsterdam as professor, which position he resigned in 1832. He published descriptions of his operations in the Gröningen hospital in 1816, in 1822, and in 1828.

Anthony Gerard van Onsenoort (1782–1841), a surgeon's apprentice, served in the army, began to teach in Löwen in 1817, and in 1822 continued teaching in Utrecht. He published *De militaire chirurgie* (1832) and *De operative heelkunde* (3 vols., 1835–37), besides several works on ophthalmology.

Christian Bernard Tilanus (1796–1883), a native of Harderwijk, studied at Utrecht, graduating in 1819, and then in Paris under Dupuytren and Lisfranc, and in 1828 became professor of surgery and obstetrics in the school at Amsterdam, where he was the first to give regular clinical teaching in surgery in the hospital. He ceased teaching in 1872.

Hans Rudolph Ranke (1849–87), a native of Kaiserwerth and a pupil of Volkmann, graduated at Halle in 1874, and in 1876 became professor of surgery at Gröningen. He contributed a number of papers to journals, but published no important work.

At the beginning of the nineteenth century the leading Italian surgeons were Scarpa, Palletta, Monteggia, and Vacca Berlinghieri.

Antonius Scarpa (1752–1832) studied at Padua under Morgagni, graduating in 1770 at the age of eighteen. Two years later he was appointed professor of anatomy and theoretical surgery at the University of Modena, and in 1783 was appointed by Joseph II., emperor of Austria, as professor of anatomy at the University of Pavia, to which was added in 1787 the chair of clinical surgery. He retained both these professorships until 1803, when he gave up anatomical teaching, but continued to teach in clinical surgery until 1812. He was the most celebrated Italian anatomist and surgeon of his day, and his talent as an artist enabled him to illustrate his discoveries in a manner which at once attracted general attention. His name is perpetuated in surgery by "Scarpa's triangle."

Giovanni Battista Palletta (1747–1832) graduated at Padua in 1769, and in 1787 became chief surgeon of the Hospital Maggiore in Milan,

and gave lessons in anatomy and clinical surgery. He was greatly beloved, and his death was considered as a public calamity in Milan.

Giovanni Battista Monteggia (1762–1815) became professor of anatomy and surgery in Milan in 1795, and was associated with Scarpa in the preparation of *Istituzioni di chirurgia* (5 vols., 1802–03; 4th ed., 7 vols., 1829–30).

Andrea Vacca Berlinghieri (1772–1826), son of Francesco Vacca Berlinghieri, professor of medicine at Pisa, studied at Paris under Desault and at London under John Hunter, and, returning to Pisa, graduated in 1791. In 1801 he became professor of surgery at Pisa, and soon acquired a great reputation.

In the middle of the century the best-known Italian surgeons were—Luigi Porta (1800–75), who studied at Pavia, was for three years in Vienna, and became professor of clinical surgery at Pavia in 1832, which position he held until his death; and Francesco Rizzoli (1809–80), professor of surgery and obstetrics in Bologna in 1840, who was distinguished as an operator and teacher.

The scheme of medical studies adopted in Austria in 1810 prescribed a five years' course in medicine or the higher surgery, and a two years' course for country doctors. In 1822 the course at the Military Medico-chirurgical Academy, or Josephinum, was extended to five years, and this college had the right to grant degrees. In 1849 much more power was given to the professors in the various universities as to the arrangement of studies, but a complete separation between the faculties and the medical associations was not made until 1873. In 1872 separate diplomas for surgery were abolished.

In Prussia a system of medical study was arranged in 1825. It provided for physicians who studied at the universities, and for what were called surgeons of the first and second class. The surgeons of the second class were surgeons' apprentices who served for a short time in a military hospital or attended a few lectures at a medico-chirurgical college; their examination was a very easy one, but demanded some knowledge of anatomy, and they were mostly comparatively uneducated men of an inferior class. The surgeons of the first class had to study at a university or a medico-chirurgical school for three years, and were not required to know Latin, as were the physicians, showing that surgery was still considered inferior to medicine. In 1852 it was ordered that there should be but one class of doctors, but the obtaining a medical degree did not give the right to practise. At present the education and the standing of physicians and of surgeons are the same throughout the empire.

During the first fourteen years of the nineteenth century the Napoleonic wars produced an urgent demand for army surgeons, especially in Austria, which was often the field of conflict. Vienna had the leading surgical schools in Germany at that time, founded by Leber in connection with the university, and by Brambilla in connection with the Military Medical School, and the principal surgeons in Southern Germany after Leber were von Kern, Rudtorffer, Wattmann, and Zang.

Vincenz Sebastian von Kern (1760–1829), professor of surgery at Laibach in 1797, became professor of practical and clinical surgery in the Vienna University in 1805, and exercised a powerful influence on

the development of surgery and surgical teaching in Germany and Northern Italy until his resignation in 1824. He greatly simplified the prevailing treatment of wounds, returning to the water-dressing of Magatus and rejecting plasters and salves, and was a skilful operator and an excellent teacher.

Franz Xav. Rudtorffer (1760–1833) commenced teaching in the great Vienna Hospital in 1801, and in 1810 succeeded Leber as professor of surgery, which position he held until he retired in 1821.

Joseph von Wattmann (1779–1866), son of a surgeon and pupil of von Kern, became professor at Laibach in 1816, at Innsbruck in 1818 and at Vienna in 1824, retiring in 1848. He was a celebrated operator and gained great reputation as a teacher.

Christoph B. Zang (1772–1835) graduated at Vienna, entered the Austrian army, and in 1806 became professor of surgery in the Josephinum. He published *Darstellung blutiger heilkünstlerischer Operationen* (4to, 1813–21)—an excellent manual of operative surgery, which reached a third edition and was translated into Italian.

In North Germany the principal surgeons of this period were Mursinna, Rust, C. J. M. Langenbeck, v. Walther, Hesselbach, and Brünninghausen.

Christian Ludwig Mursinna (1744–1823), a barber's apprentice, entered the Prussian army in 1761 under Theden. In 1787 he became surgeon-general, and professor of surgery in the military medical school at Berlin, which position, in connection with that of surgeon to the Charite, he retained after his retirement from military service in 1809. He was a skilful operator and a good administrator, who greatly improved the medical service in the Prussian army, but wrote little except occasional addresses and papers for journals.

Joh. Nepomuk Rust (1775–1840) studied in Vienna and Prague, and became professor of surgery at Cracow in 1803. From 1810 to 1813 he was one of the surgeons of the General Hospital in Vienna, and in 1816 he succeeded Mursinna in the army medical school at Berlin, becoming professor in the University of Berlin in 1824.

Conrad Joh. M. Langenbeck (1776–1851) studied at Jena, Vienna and Würzburg, and in 1802 settled in Göttingen, where he soon began to teach anatomy and surgery. In 1814 he became professor of anatomy and surgery and surgeon-general of the Hanoverian army. In 1802 he published a treatise on lithotomy; in 1806 the first volume of his *Bibliothek für die Chirurgie*, of which the eighth and last volume appeared in 1828; and in 1822 the first volume of his *Nosologie und Therapie der chirurgischen Krankheiten, etc.*, of which vol. v. appeared in 1850. He was a skilful anatomist and operator, modifying and improving the technique, and a celebrated teacher.

Philip Franz v. Walther (1782–1849) was educated at Heidelberg and Vienna, and became professor and surgeon to the hospital at Bamberg when he was only twenty-one years old. In 1804 he became professor of physiology and surgery at Landshut, and soon acquired a high reputation as an operator and teacher. In 1818 he accepted a call to the newly-organized university at Bonn, where he soon became the leading German surgeon of his time. In 1830 he went to Munich as professor of surgery in the university, which had been transferred to that city

from Landshut, and as director of the surgical clinic in the General Hospital, in which positions he remained until his death. He was the founder of modern surgery in Bavaria, and his physiological training was of great assistance in his surgical teaching. He wrote a *System der Chirurgie* (1833) and numerous papers for periodicals.

Franz Caspar Hesselbach (1759–1816) was a pupil of Von Siebold at Würzburg, and his assistant in anatomical demonstrations. His principal contributions to surgery are his papers on hernia, published in 1806, 1814, and 1815, in the first of which he gives the first distinct description of the two forms of inguinal hernia.

Hermann Joseph Brünninghausen (1761–1834) was professor of surgery at Würzburg in the early part of the century, and published his *Erfahrungen und Bemerkungen über die Amputation* in 1818.

Between 1825 and 1850 the leading German surgeons were Graefe, Dieffenbach, and Chelius, in addition to the survivors of those already referred to.

Carl Ferdinand von Graefe (1787–1840) studied at Dresden, Halle, and Leipzig, in 1810 became professor and director of the surgical clinic in the newly-founded University of Berlin, and from 1813 to 1815 served as surgeon-general of division in the army. In 1816 he first performed suture for congenital cleft palate, and then devised blepharoplasty and rhinoplasty, which he introduced to notice. He was one of the first to resect a portion of the lower jaw, and the first in Germany to ligate the innominate artery.

Johann Friedrich Dieffenbach (1792–1847) was a native of Königsberg, where he studied from 1818 to 1820, when he went to Bonn and became the pupil of von Walther. In 1821 he went to Paris and Montpellier, attending the clinics of Dupuytren and Delpech, and in 1822 graduated at Würzburg, his thesis, *Nonnulla de regeneratione et transplantatione*, indicating the trend of his studies. In 1823 he went to Berlin and devoted himself largely to plastic surgery. In 1829 he became surgeon to the Charité, and in 1832 professor extraordinary in the university, at which time he began his work in orthopædic surgery. In 1829 he devised the section of the tendons of the ocular muscles for strabismus, which made a great sensation in the surgical world. In 1840, after the death of von Graefe, he became professor in the university and director of the surgical clinic. He made many valuable contributions to methods in plastic surgery and tenotomy, which are summed up in his *Operative Chirurgie* (2 vols., 1845–48). His enthusiasm for novelties led him into some blunders, as in his publications on the cure of stammering by subcutaneous section of the muscles of the tongue, but he was a great surgeon, a most skilful operator, and an extremely popular clinical teacher.

Max. Jos. von Chelius (1794–1876), a native of Mannheim, graduated at Heidelberg in 1812, after which he studied under Walther at Landshut and Vienna, and became professor at Heidelberg in 1819. Here he soon founded a surgical and ophthalmological clinic, and in 1822–23 published his *Handbuch der Chirurgie*, which for the next twenty-five years was the best-known manual in Germany, and indeed in Europe, having been translated into English, French, Italian, Danish, and Dutch, and the eighth German edition having been issued in 1857.

The English translation by South (in 1847) is especially valuable, being nearly doubled in size by the notes of the translator, and permitting of a direct comparison of the English and German surgery of that day. He was one of the best-known surgeons in Europe and had many distinguished pupils.

To this period also belong von Textor, Jaeger, Blasius, Wutzer, von Ammon, Wernher, Kuhl, Grossheim, Fricke, Mojsisovics, Holscher, and Benedict.

Kajetan von Textor (1782–1860) studied at Landshut under von Walther and graduated in 1808, after which he spent two years in Paris mainly following the teaching of Boyer, and a season at Pavia under Scarpa. In 1816 he became professor of surgery at Würzburg, and held this position until 1853 with the exception of the years 1832–33. He published *Grundzüge zur Lehre der chirurgischen Operationen, etc.*, in 1835, and some small monographs. His chief surgical contributions related to resections, in which he was a very skilful operator. His son Carl (1815–80) became assistant professor of surgery at Würzburg in 1850, and contributed a number of surgical papers to periodicals.

Michael Jaeger (1795–1838) graduated at Würzburg in 1819, and in 1826 succeeded Schreger as director of the surgical clinic at Erlangen, becoming professor of surgery in 1831. In 1832–33 he was professor of surgery at Würzburg during von Textor's absence, after which he returned to his old position at Erlangen. He contributed materially to the literature of resections and of diseases of the bones and joints.

Ernst Blasius (1802–75), a native of Berlin, studied at the Friedrich Wilhelm Institut and graduated in 1823, after which he served four years in the army, and then settled in Halle, where he became professor of surgery in 1834. His principal work was his *Handbuch der Akiurgie* (3 vols. and atlas, 1830–33), but he also published collections of cases and essays, a treatise on amputations, and numerous papers in the journals.

Carl Wilhelm Wutzer (1789–1863), a native of Berlin, studied at the Pépinière, served in the army, and became director of the surgical school at Münster in 1821. In 1830 he succeeded Weinhold as professor of surgery at Halle, and in 1833 took the same chair at Bonn. He contributed numerous articles to periodicals, but wrote no important works, and is best known as the originator of the method for the radical cure of inguinal hernia which bears his name. He was a skilled anatomist, a good operator, and a painstaking, careful teacher.

Friedrich August von Ammon (1799–1861) studied in Leipzig and Göttingen, graduating in 1821, and settled in Dresden, where he became professor in the surgical school in 1828, resigning in 1837. The greater part of his numerous publications relate to ophthalmology, but he also devoted much attention to plastic surgery and to orthopædia. In connection with Baumgarten he published *Die plastische Chirurgie nach ihren Leistungen kritisch dargestellt* (1842), and in the same year appeared his *Die angeborenen Krankheiten des Menschen, etc.* (in folio with plates), which is a classic. Another finely-illustrated work is his *Klinische Darstellung der Krankheiten und Bildungsfehler des menschlichen Auges, etc.* (fol., 1838–41).

Adolph Wernher (1809–83) graduated in 1832 at Giessen, where

he became professor of surgery and director of the surgical clinic in 1837, retiring in 1878. His *Handbuch der allgemeinen und speciellen Chirurgie* (4 vols., 1846–47) was an excellent manual, of which the first volume of a second edition appeared in 1862–63.

Karl August Kuhl (1774–1840) studied at Leipzig, graduating in 1803, after which he went to Vienna, London, and Paris. In 1817 he became assistant professor, and in 1824 professor, of surgery at Leipzig. He was a bold and skilful operator, and ligated the innominate, the subclavian, and both carotids, all of which cases he described, but he wrote no important work and made no special contributions to surgical progress.

Ernst Leopold Grossheim (1799–1844), a pupil of the Friedrich Wilhelm Institut in Berlin, was an army surgeon and a teacher in the surgical school at Münster, who published a *Lehrbuch der operativen Chirurgie* (3 vols., 1830–35).

Joh. Carl George Fricke (1790–1841) studied at Göttingen, where he graduated in 1810, after which he studied in Berlin under von Graefe. In 1814 he settled in Hamburg and became surgeon of the General Hospital. He published the records of his clinical work in the *Annalen der chirurgischen Abtheilung des allg. Krankenhauses in Hamburg* (2 vols., 1828–33), and in various journals, especially in the *Zeitschrift f. d. ges. Medicin*, of which he was one of the editors. His contributions relate to blepharoplasty, the non-mercurial treatment of syphilis, the treatment of orchitis by compression, the torsion of arteries, the forceps and vaginal speculum known by his name, etc.

George Mojsisovics (1799–1860), a Hungarian, studied in Budapest and Vienna and graduated in 1826. In 1828 he became assistant in the surgical school at Vienna, and in 1832 first surgeon of the General Hospital. He published nothing of any importance.

George P. Holscher (1792–1852) studied at Göttingen, and in London under Astley Cooper, and settled in Hannover, where he became a teacher in the surgical school and editor of the *Hannoversche Annalen für die gesammte Heilkunde* (1836–47). His publications were almost entirely journal articles.

Traugott Wilh. Gustav Benedict (1785–1862) studied at Leipzig, graduating in 1810, and in 1812 became professor at Breslau, where he acquired a reputation as an ophthalmologist. His principal surgical publication is his *Lehrbuch der allgemeinen Chirurgie und Operationslehre* (1842).

The next group of German surgeons to be noted includes von Langenbeck, Stromeyer, Heyfelder, von Pitha, Schuh, von Bruns, Günther, Middledorpf, Busch, Linhart, Wagner, and Baum.

Bernard Rudolph Konrad von Langenbeck (1810–87), the most distinguished German surgeon of the nineteenth century, took his doctor's degree at Göttingen in 1835, became professor of surgery at Kiel in 1842, and succeeded Dieffenbach in the chair of surgery at Berlin in 1847. In conjunction with his pupils, Billroth and Gurlt, he established the *Archiv für klinische Chirurgie* in 1861, a journal which has contained the most important contributions to surgery made by German surgeons since that date, and he was the founder of the *Deutsche Gesellschaft für Chirurgie* in 1872. Langenbeck wrote no manual or system

of surgery, but contributed numerous papers to the *Archiv für klinische Chirurgie*, his largest work being his *Chirurgische Beobachtungen aus dem Kriege* (251 pp. 8vo, Berlin, 1874). His operations and improvements of the technical methods of surgical operations are too numerous to mention. Some of the most important of them relate to plastic surgery of the nose and of the hard palate, and to operations for tumors at the base of the cranium, for removal of the tongue, etc. His greatest contribution to surgery, however, has been his pupils, among whom may be numbered nearly every prominent surgeon in Germany of the present day.

Georg Friedrich Louis Stromeyer (1804–76), son of Chr. Fr. Stromeyer, surgeon to the king of Hannover, studied at Hannover, Göttingen, and Berlin, and graduated in 1826. In 1829 he began to teach in the surgical school at Hannover, in 1838 succeeded Jaeger as professor of surgery at Erlangen, in 1842 accepted the same chair in Freiburg, and in 1847 succeeded Langenbeck at Kiel. He became surgeon-general of the Schleswig-Holstein army, serving in the war of 1849, and surgeon-general of the Hannoverian army in 1854, serving in the war of 1866. His chief contributions to the art were connected with orthopædic surgery and tenotomy, and especially with resections in military surgery. He performed subcutaneous section of the tendo Achillis in 1831, being the first after Delpech to do so. His principal publications were *Beiträge zur operativen Orthopädik* (1838), *Handbuch der Chirurgie* (2 vols., 1844–48), and *Maximen der Kriegsheilkunst* (1855).

Johann Ferdinand Heyfelder (1798–1869), student at Berlin, Würzburg, and Breslau, graduating in 1820, in 1841 succeeded Stromeyer as professor of surgery at Erlangen, which position he resigned in 1854. The latter part of his life was spent in St. Petersburg. He was a learned surgeon, a skilful operator, a teacher of great reputation, and a voluminous writer upon many subjects besides surgery. He is best known by his treatise *Ueber Resectionen und Amputationen* (1854), which is a standard work upon the subject. His son, Oscar Heyfelder (1828–?), studied at Heidelberg and Erlangen, graduating in 1851, and entered the Russian army medical service in 1859. He published *Lehrbuch der Resectionen* (2d ed. 1863, and translated into French in the same year), *Kriegschirurgisches Vade Mecum* (1874), and numerous articles in the journals.

Franz von Pitha (1810–75), a native of Bohemia, studied at Prague, graduating in 1836, and in 1843 succeeded Fritz as professor of surgery in the University of Prague, in which position he soon obtained a high reputation as a teacher. In 1854 he accepted the chair of surgery in the Medico-chirurgical Josephs Academy in Vienna, re-established for the purpose of training medical officers for the Austrian army. His name is best known in connection with the *Handbuch der allgemeinen und speciellen Chirurgie*, edited by Billroth and himself (1865–82). He was a skilful diagnostician and operator and a cultured and polished gentleman.

Franz Schuh (1804–65) studied in Vienna, graduating in 1831, became surgeon to the General Hospital in Vienna in 1837, and professor of surgery in 1842. He was an excellent practical teacher and writer, aided much in increasing the reputation of the school, and con-

tributed numerous papers to the journals. His principal books are—*Ueber die Erkenntniss der Pseudoplasmen* (1851), *Pathologie und Therapie der Pseudoplasmen* (1854), and *Abhandlungen aus dem Gebiete der Chirurgie und Operationslehre* (published after his death, in 1867).

Victor von Bruns (1812–83), student at Tübingen, graduating in 1836, became professor of surgery at Tübingen in 1843, which position he held until 1882. He was one of the founders of modern laryngology, and was the first to remove a laryngeal growth through the natural passages. His principal works are—*Chirurgischer Atlas* (fol., 1853–60), *Handbuch der praktischen Chirurgie* (2 vols., 1854–59), *Die Laryngoskopie und die laryngoskopische Chirurgie* (1865), *Chirurgische Heilmittellehre* (2 vols., 1868–73), *Die galvanokaustischen Apparate, etc.* (1878), and *Die Amputation der Gliedmassen durch Zirkelschnitt mit vorderem Hautlappen* (1879).

Gustav Biedermann Günther (1801–66) studied at Leipzig, graduating in 1824, and in the following year became an assistant to Fricke in the General Hospital at Hamburg. In 1831 he was appointed professor of surgery in Kiel, and in 1841 accepted the same position at Leipzig. He was a good anatomist and a careful, painstaking teacher, but was not distinguished as an operator. His principal work is his *Lehre von den blutigen Operationen am menschlichen Körper* (4to, 1859–65).

Albrecht Theodor Middeldorpf (1824–68) studied at Breslau and Berlin, graduating in 1846, and in 1856 became professor of surgery at Breslau. He introduced the use of the galvano-cautery, made improvements in the treatment of fractures and of gastric fistula, and was one of the best clinical teachers of his time. His principal publications are—*Beiträge zur Lehre von den Knochenbrüchen* (1853), *Die Galvanocaustik* (1854), *Ueberblick über die Akidopeirastik* (1856), and *Commentatio de fistulis ventriculi externis, etc.* (1859).

Carl David Wilhelm Busch (1826–81), son of the celebrated obstetrician Dietrich Wilh. Heinr. Busch, studied in Berlin, graduating in 1848, and after extensive travels became an assistant in Langenbeck's clinic in 1851. In 1854 he accepted a call to Bonn as professor of clinical surgery, and remained there until his death. He was a voluminous writer and made valuable contributions to the literature of gunshot wounds, fractures and dislocations, diseases of the joints, plastic surgery, and hernia, the majority appearing in periodicals and transactions. His *Lehrbuch der Chirurgie* (2 vols., 1857–69) was his principal work.

Wenzel von Linhart (1821–77), the son of a surgeon, studied in Vienna, graduating in 1844; became an assistant of Dumreicher, and in 1856 accepted a call to Würzburg as professor of clinical surgery. He was a skilled anatomist and operator and an excellent teacher. His principal works are his *Compendium der chirurgischen Operationslehre* (1856; 4th ed. 1874) and *Vorlesungen über Unterleibs-Hernien* (1866; new ed. 1882).

Carl Ernst Albrecht Wagner (1827–70), son of a celebrated physician, studied in Berlin, graduating in 1848; became an assistant in Langenbeck's clinic, surgeon to the hospital in Dantzig in 1853, and in 1858 professor of surgery in Königsberg, where he acquired great reputation as a teacher.

Wilhelm Baum (1799–1883) studied at Königsberg and Berlin,

graduating in 1822; continued his studies in Vienna, London, and Paris; in 1830 became surgeon in charge of the municipal hospital at Dantzig; in 1842 accepted the position of professor of surgery at Greifswald; and in 1849 took the same chair at Göttingen, from which he retired in 1867. He was a learned man and a good teacher, but published nothing.

To this period also belong Zeis, Stilling, and Heine.

Edward Zeis (1807–68), a native of Dresden, studied at Leipzig, Bonn, and Munich, graduating at Leipzig in 1832, after which he settled in Dresden. From 1844 to 1850 he was professor of surgery at Marburg, at the end of which period he returned to Dresden and became surgeon to the city hospital. His principal publications are—*Handbuch der plastischen Chirurgie* (1838) and *Die Literatur und Geschichte der plastischen Chirurgie* (1863–64).

Benedict Stilling (1810–79) studied at Marburg, graduating in 1833, and became assistant in the surgical clinic. Soon after he settled in Cassel, where he remained for the rest of his life. He is much better known as a physiologist and investigator of the nervous system than he is as a surgeon, but he was the first ovariotomist in Germany, and between 1856 and 1870 published several papers on stricture and on internal urethrotomy.

Jacob von Heine (1800–79), of a family of instrument-makers and orthopædists, student at Würzburg, graduated in 1827, and established an orthopædic hospital in Cannstatt which became celebrated. His principal publications are—*Beobachtungen über Lähmungszustände der untern Extremitäten und deren Behandlung* (1840), *Ueber spontane und congenitale Luxationen, etc.* (1842), and *Spinale Kinderlähmung* (1860).

Here also may be mentioned Carl Wilhelm von Heine (1838–77), son of Jacob v. Heine, and professor of clinical surgery in the new medical faculty of Innspruck in 1869, who wrote on gunshot wounds of the lower extremities, hospital gangrene, etc.; August Gustav Herrmann (1831–74) of Prague, author of *Compendium der Kriegs-Chirurgie* (1870); Fried. Wilh. Theodore Ravoth (1816–78) of Berlin, whose most important works relate to the treatment of hernia; Ernst Ludwig Schillbach (1825–?) of Jena, author of *Beiträge zu den Resectionen der Knochen* (1858–60); Hermann Demme (1802–67), professor of surgery in Berne, and his son, Carl Hermann Demme (1831–64), author of some valuable papers on military surgery; August Burow (1809–74) of Königsberg, a pupil of Dieffenbach, author of numerous papers on ophthalmology, the open treatment of wounds, and plastic surgery; Hermann Julius Paul (1824–77) of Breslau, author of *Die conservative Chirurgie* (1854; 2d ed. 1859) and *Lehrbuch der speciellen Chirurgie* (1861); Johann Balassa (1812–69) of Budapest, celebrated as an operator in lithotomy and plastic surgery; and Joseph Blazina (1812–85), who graduated in 1841 at Prague, where he became professor of surgery.

Between 1850 and the present time the leading surgeons of Germany, besides those already mentioned, and those who, being yet living, do not come within the scope of this paper, were Loeffler, Wilms, Simon, Thaden, Lücke, Hueter, Maas, Leisrink, Vogt, Volkmann, and Billroth.

Gottfried Friedrich Franz Loeffler (1815–74) studied at the Friedrich Wilhelm Institut in Berlin, and became one of the most distinguished of the German army surgeons. His principal works are—*Grundsätze und Regeln für die Behandlung der Schusswunden im Kriege* (1859) and *Das preussische Militär Sanitätswesen und seine Reform* (1868–69).

Robert Ferdinand Wilms (1824–80) studied at Berlin, graduating in 1846, and in 1848 became an assistant of Bartels in the Bethanien Hospital, of which he was placed in charge in 1862. He was one of the leading surgeons in Berlin, and was popular as a teacher, but wrote little beyond the reports of his hospital.

Johann Dumreicher (1815–80) graduated at Vienna in 1838, became assistant to Wattmann, and took charge of one of the surgical clinics in 1849. He wrote very little.

Christoph Jac. Fried. Ludw. Gustav Simon (1824–76) studied at Giessen and Heidelberg, graduating in 1848, and at once entered the Hessian army, in which he became medical director in 1861, in the same year was appointed to the chair of surgery at Rostock, and in 1867 accepted a call to the same position in Heidelberg. His first publication was *Ueber Schusswunden, etc.* (1851), soon after which, on a visit to Paris, he became acquainted with Jobert's method of operating for vesico-vaginal fistula, and on his return established a small hospital, acquired great reputation as an operator for such affections, and published a number of papers on the surgery of the female genitals. After going to Heidelberg he performed the first operation for nephrectomy in 1869, and published his *Chirurgie der Nieren* in 1871, the second part appearing after his death, in 1876. He was a bold and skilful surgeon, and made numerous improvements in methods of investigating and treating surgical affections. He was also a voluminous writer, but his publications were concise monographs, and not large, systematic treatises.

Adolf Georg Jacob von Thaden, a native of Holstein, studied in Heidelberg and Kiel, graduating in 1853, after which he was for two years an assistant of Esmarch, and in 1861 became surgeon of the new city hospital at Altona. He was a skilful, scientific surgeon.

George Albert Lücke (1827–94), a native of Magdeburg, studied at Heidelberg, Halle, and Göttingen. He became assistant to Blasius at Halle in 1854, and soon after became assistant to von Langenbeck in Berlin, and privatdocent. In 1865 he became professor of surgery at Berne, and in 1872 accepted the same position at Strasburg, where he remained until his death.

Carl Hueter (1838–82), son of a well-known obstetrician of Marburg, graduated in 1859, after which he studied in Vienna, London, and Paris, and became a privatdocent in Berlin and an assistant of Langenbeck. In 1868 he succeeded Simon as professor of surgery at Rostock, and in 1869 accepted a call to the same chair at Greifswald. Hueter was a scientific surgeon, giving great attention to pathology and bacteriology; he was also a skilful operator, made many improvements in method in resections, tracheotomy, excision of the rectum, etc., and was a voluminous writer. His principal works are—*Klinik der Gelenkkrankheiten* (1870–71; 2d ed. 1876–78), *Die allgemeine Chirurgie* (1873), and *Grundriss der Chirurgie* (1880–82).

Hermann Maas (1842–86) graduated at Breslau in 1865, and became assistant to Middeldorpf, and privatdocent, and in 1877 professor of surgery at Freiberg. His chief work was his *Kriegschirurgische Beiträge aus dem Jahre 1866* (published in 1870).

Heinrich Wilh. Franz Leisrink (1845–85) studied in Göttingen and Kiel, graduating in 1868, and settled in Hamburg, where he became distinguished as a surgeon and contributed some valuable papers to periodicals. His most important work was *Die moderne Radikal-Operation der Unterleibsbrüche, eine statistische Arbeit* (1885).

Paul Fried. Immanuel Vogt (1849–85) studied at Greifswald, graduating in 1865, and in 1882 succeeded Hueter as professor of surgery. His principal works were—*Die chirurgischen Krankheiten der oberen Extremitäten* (1881) and *Mittheilungen aus der Chirurgischen Klinik in Greifswald* (1884).

Richard von Volkmann (1830–89), son of Alfred Wilhelm Volkmann, professor of anatomy and physiology in the University of Halle, was educated at Halle, Giessen, and Berlin, and obtained his medical degree in 1854. He was an assistant in the surgical clinic of Professor Blasius, in 1857 became privatdocent, and in 1867 professor of surgery at Halle. With Langenbeck and Simon he founded the German Surgical Association, and in 1874 said before this society: "There is no such thing as luck in surgery: for every case of pyæmia, erysipelas, and necrosis after amputation the surgeon who treats it must be held responsible." His contributions to surgery and to surgical literature were numerous and important, and he was the first German carefully to study Lister's methods and to urge their adoption upon German surgeons. Volkmann was a poet as well as a surgeon, but issued his poems under another name, and few persons know that Richard Leander, the German poet, is the same person as Richard Volkmann, the famous surgeon of Halle.

Theodor Billroth (1829–94), a native of Bergen on the island of Rügen, studied at Greifswald, Göttingen, and Berlin, graduating at the latter university in 1852. He became assistant to von Langenbeck, privatdocent in 1856, professor of clinical surgery at Zurich in 1860, and professor of surgery in the University of Vienna in 1867, succeeding Franz Schuh. During the last twenty-five years he has been one of the most celebrated surgeons in the world as an investigator in surgical pathology, a bold and successful operator, a voluminous writer, and a clinical teacher. He first excised the larynx for cancer in 1873, first successfully excised a large portion of the stomach in 1881, and gave a strong impetus to the progress of operative surgery of the intestinal tract. His lectures on surgical pathology and therapeutics have passed through many editions and translations; his reports on clinical surgery were translated into English in 1881, and the total number of his published books and papers was about one hundred and forty.

The history of surgery in Denmark is merely the old story of the barbers and barber surgeons until near the end of the eighteenth century. The University of Copenhagen was founded in 1479, and possessed a nominal medical faculty consisting of two or three physicians who read the works of Galen and Avicenna. In 1559 some attempt was made to introduce anatomical studies, and the young physicians had to travel in

foreign countries before completing their studies and obtaining their degree. In 1577, Frederick II. issued statutes for the Collegium Chirurgicum of Copenhagen, in which it was ordered, seeing that from ancient time there had been only six barbers in the city—*i. e.* barber surgeons—that the term of apprenticeship should be three years, and then the apprentice was to travel in foreign countries for four consecutive years. Travelling lithotomists had to obtain the approval of the corporation before they were allowed to operate. Controversies between the physicians and the barbers occurred as a matter of course. In 1736, Simon Krueger (1687–1760), a barber surgeon, with others, founded the "Theatrum Anatomico-chirurgicum," a school for teaching anatomy and surgery, which prospered for the next twenty-four years, but was suppressed in 1772. In 1783 the Academia Chirurgica was created. Krueger was an excellent teacher, but wrote very little.

Heinrich von Moinichen, a surgeon of Copenhagen, published in 1665 his *Observationes Medico-chirurgicæ*, of which there were three later editions.

Georg Heuermann (1722–68), professor of medicine in the University of Copenhagen, published in 1754–57 his *Abhandlung der vornehmsten chirurgischen Operationen am menschlichen Körper*, a well-arranged and illustrated work.

Alexander K. Koelpin (1731–1801) graduated in 1763, after which he studied under Hunter in London and Le Cat in Rouen, and returned to Copenhagen and became chief surgeon of the Friedrichs Hospital in 1766. In 1785 he became professor of the newly-organized surgical academy.

Henry Callisen (1740–1824), a native of Holstein and a pupil of Simon Krueger, passed his preliminary examination in 1767, after which he studied at Paris and under William Hunter in London. Returning to Copenhagen, he became chief surgeon of marines, and took his degree as doctor in 1772, and in 1773 succeeded Burger as professor of surgery. His *Institutiones chirurgicæ hodiernæ* (1777) and his *Systema chirurgiæ hodiernæ, etc.* (1778) passed through several editions and translations, and were popular text-books until the beginning of the nineteenth century.

Adolf Carl Peter Callisen (1787–1866), a nephew of Henry Callisen, graduated at Kiel in 1809, and became a professor in the Surgical Academy in Copenhagen in 1817. In 1842 he was professor of surgery in the university. His best-known work is his *Medicinisches Schriftsteller-Lexicon der jetzt lebenden Aerzte, etc.* (in 33 vols. 8vo, 1830–45).

The first distinguished surgeon in Sweden was Olaf Acrel (1717–1806), who was chief surgeon of the Seraphim Hospital in Stockholm after its foundation in 1752. He became professor of surgery in 1755, and his teachings had great influence in the development of surgery in Sweden. His principal work is *Kirurgiska Handelser* (Stockholm, 1759), which was translated into Dutch in 1771, and into German in 1772 and 1777.

Peter af Bjerkin (1755–1818), a pupil of John Hunter and a surgeon in the Finnish army, became chief surgeon of Stockholm in 1809. He was the greatest Swedish surgeon in the early part of this century, but wrote nothing of importance.

The first professor of surgery and obstetrics at the University of Christiania was Magnus Andreas Thulstrup (1769–1844), a native of Copenhagen, who entered the Norwegian military medical service, became surgeon-general, and in 1814 professor. He wrote very little.

Jacob Christian Johan Henrik Gundelach Moeller (1797–1845), a native of Jutland, studied in Copenhagen, and in 1842 became professor of surgery, and was a distinguished clinical teacher.

Joh. August Liborius (1802–1870), a surgeon of Gothenburg, was well known in his day as a skilled practitioner, and wrote on the starched bandage, on hemorrhoids, and on herniotomy.

The leading surgeon of Sweden in recent years was Carl Gustav Santesson (1819–86), a native of Gothenburg, who graduated at Upsala in 1846, and became professor of surgery in the Stockholm school in 1849, retiring in 1885. He contributed a number of papers to the journals, and published *Om höftleden och ledbrosken uti anatomiskt pathologiskt och chirurgiskt hänseende, etc.* (Stockholm, 1849). He was a skilled surgeon, a great teacher, and an accomplished gentleman.

There is little to be said of the history of surgery in Russia prior to the middle of the nineteenth century. The priests were the physicians for the great mass of the people, but a few medical men were brought from other countries during the sixteenth, seventeenth, and eighteenth centuries for the service of the court. Among these was Bidloo, who induced Peter I. to found a medico-chirurgical college and hospital in the early part of the eighteenth century. In 1768, Simon Zybelin was professor of anatomy and surgery in the University of Moscow, and in 1812, Andreas Sydoratzky (1788–1815) was a teacher of surgery in the same university, but no record of their work is accessible.

Leo Nagumowitsch (1792–1815), an army surgeon, published, in Russian, in 1832, a handbook on the treatment of gunshot wounds, and Joseph Czekierski (1777–1826), a surgeon of Warsaw and professor of surgery in the medical faculty created in 1809, published a manual of surgery (4 vols., 1817–18).

Elias Bujalski (1789–1864), anatomist in the Military Medico-chirurgical School at St. Petersburg, published his *Tabulae anatomico-chirurgicae* in 1828 and again in 1852.

Christian Salomon, professor of surgery at St. Petersburg, published his handbook of operative surgery in Russian, in two volumes, in 1840.

The first distinguished Russian surgeon was Nikolaus Iwanowitsch Pirogoff (1810–81), who studied at Moscow and Dorpat and obtained his degree in 1832, after which he studied in Berlin and Göttingen for two years. On his return he gave lectures on surgery at Dorpat, being the first Russian professor there. After five years in Dorpat, in 1840, he was appointed professor of surgery in the Medico-chirurgical Academy of St. Petersburg. His attempts to improve the sanitary condition of the military hospital connected with the academy created much ill-feeling, and for a time he was considered and treated as insane. During the Crimean War he was active at Sevastopol, and incurred ill-will by his denunciation of the abuses connected with the Russian military administration during the siege, the result of which was that he was compelled to resign his professorship in the academy at St. Petersburg. His contributions to surgery were numerous in relation to gunshot

wounds, amputations, and the surgery of bones, and his name is connected with a method of osteoplastic amputation through the foot devised by him in 1854. The list of his publications is a long one, the most important being his *Recherches pratiques et physiologiques sur l'éthérisation* (1847); *Rapport médical d'un voyage au Caucase, contenant la statistique comparative des amputations, etc.* (1849); *Anatome topographica sectionibus per corpus humanum congelatum, etc.* (fol., 1852–59); *Chirurgische Anatomie der Arterien-staemme und Fascien* (1861); and *Grundzüge der allgemeinen Kriegschirurgie* (1864).

Little is known of the Russian surgeons who wrote only in Russian, for very few of their works have been considered worth translating.

Ivan Rklizky (1805–61), professor of clinical surgery at St. Petersburg, in 1847 published a treatise on operative surgery in Russian, of which there were two later editions.

Peter Dubovizki (1815–67), professor of surgery at Kasan, in 1837 published a treatise on hemorrhage, and one on lithotripsy in 1838.

Sablozky-Desjatovski (1816–82), professor of surgery at the Medical Academy of St. Petersburg in 1842, wrote on hernia, diseases of the testicle, and venereal diseases.

Polycarp Girsztowt (1827–77) studied in St. Petersburg, was an army surgeon in the Crimea in 1853–56, and became professor of surgery in Warsaw in 1860. He contributed to periodical literature, but wrote no special work of any importance.

Hippolyt Korzeniowski (1827–79) studied at St. Petersburg, became professor of surgery in Warsaw in 1868, and professor of surgery in St. Petersburg in 1871.

Karl Daniel von Haartman (1792–1877) was professor of surgery and obstetrics in the University of Helsingfors from its foundation in 1833. He published *Casus chirurgici* in 1815.

One of the most distinguished and best known of modern Russian surgeons was Julius Szymanowsky (1829–68), a native of Riga, who studied at Dorpat, graduating in 1856. In 1858 he went to Helsingfors as assistant professor of surgery, and in 1861 accepted a call to Kiew, where he acquired a great reputation. He was a skilful operator and an excellent teacher. His principal publications are *Der Gypsverband mit besonderer Berücksichtigung der Militärchirurgie* (1857) and a treatise on operative surgery in Russian (1864–65), of which the first part was translated into German and published in 1872.

Carl Reyher (1846–90), a native of Riga, studied at Dorpat, graduating in 1871, became an assistant of von Bergmann, and privatdocent, entered the Russian army medical service, and became a distinguished surgeon and teacher in St. Petersburg. His principal publications relate to antiseptic methods, diseases of the joints, laryngotomy, and gunshot wounds.

Upon the establishment of the Spanish rule in Mexico the medical system of Spain was established with it, including the barbers and the barber surgeons. The first provision for the examination of physicians and surgeons appears to have been made in 1646, being a board composed of three persons, two of whom were physicians connected with the university. From this date to 1700 it is reported that forty-seven physicians, one surgeon, three apothecaries, and eighteen barbers were

examined and authorized to practise. Evidently the barbers had the greater part of the surgical practice. In 1742 it was ordered that no surgeon should undertake to practise medicine nor to give purgatives or emetics or diaphoretics or other drugs, and that no apothecary should put up prescriptions of a surgeon for such drugs. In short, it is the old story of an attempt by the physicians to suppress the surgeons. In 1719 it was ordered that in the examination of the surgeons no one should be approved who had not seen some practice in hospitals, and in 1720 all the practitioners of medicine, surgery, anatomy, and algebra were notified of the necessity of passing this examination. (By "algebra" here is meant "bone-setting.") (See "Historia de la Medicina de 1646–1700," by Dr. Reyes, *Gaceta Médica de Mexico*, 1865–66.)

For a long time after the first settlements on the Atlantic coast of North America very few educated physicians were among the immigrants. The clergy included many men of learning, talents, and piety, and some distinguished lawyers accepted offices in the new colonies, but there was little attraction for skilled physicians. Some of the so-called "ship surgeons" remained, having commenced by practising on shore while their vessels were in port. The following extract from the Dutch records, dated February 2, 1652, contains a notice of these barber surgeons:

"On the petition of the Chirurgeons of New Amsterdam, that none but they alone be allowed to shave; the Director and Council understand that shaving doth not appertain exclusively to chirurgery, but is an appendix thereunto; that no man can be prevented operating on himself, nor to do another this friendly act, provided it be through courtesy and not for gain, which is hereby forbidden." It was then further *Ordered*, that ship-barbers shall not be allowed to dress any wounds, nor administer any potions on shore, without the previous knowledge and special consent of the petitioners, or at least of Doctor La Montague.

In 1662 an act regulating chirurgeons' accounts was passed in Virginia (*Hen. Stat. Va.*, vol. ii. p. 109).

At a somewhat later period in Connecticut the popular feeling seems to have been rather in favor of ignorance in a medical man, if we may judge from the fact that in 1766 the physicians of Litchfield county, having endeavored to form a medical association and having applied for a charter for that purpose, were refused by the General Assembly on the ground that it would form a monopoly, and that as to quacks and ignorant men it was shown that they never administered any physic without the prayers of the minister (which cannot be said of the educated physicians), and that no medicine can be serviceable without the blessing of God. (See Peters' *General History of Connecticut.*)

In the early days of New England medicine was in its primitive stage, being in the hands of the clergy. The earliest practitioners or writers on medical subjects were clergymen, many of whom had regularly studied medicine in order to fit themselves for the duties of their new field, just as some of those intending to be missionaries do at the present day. For example, Charles Chauncy, the second president of Harvard College, graduated in both divinity and medicine at Cambridge, and is said to have been of the opinion that there ought to be no distinction between them, educating his six sons in both professions.

The first printed document relating to medicine issued in New England is by a clergyman, Thomas Thatcher, who came to this country in 1685. It is a broadside sheet or poster headed "Brief Rule to Guide the Common People of New England How to Order Themselves and Theirs in the Small Pocks or Measels." This is usually said to be the first medical work published in America, but several were printed in Mexico during the sixteenth century, as, for example, *Alphonso Lopez de Hinojoso summa y recopilacion de cirugia con un arte para sangrar y examen de Barberos: Va añadido en esta secunda editione, el origin y nacimiento de las reumas* [etc.]. (Mexici, 1595, 4to.)

The first methodical attempt at the regulation of practice appears to have been made by Virginia in 1736 in an act regulating fees and the accounts for the practice of physic. This fixed the fee for the ordinary surgeons or apothecaries at five shillings a visit within five miles, and ten shillings within ten miles, but those persons who have studied physic in any university and taken a degree therein are allowed double these rates.

In 1760 an act was passed by the city of New York forbidding any one to practise as a physician or surgeon in said city until he should have been examined and approved by a board composed of "one of his Majesty's council, a judge of the supreme court, the attorney-general, and the mayor," who may call in to their assistance such person or persons as they think fit. A similar law was passed in New Jersey in 1772, the examiners being any two of the judges of the supreme court. In Maryland, the District of Columbia, and South Carolina the business of examination and licensing was placed in the hands of the medical societies. The distinction between physician and surgeon soon disappeared, and there is no trace of separate organizations for these two classes of practitioners.

The majority of the regularly educated physicians in this country in 1776 were graduates of the University of Edinburgh, the first American-born graduate of that school having been John Moultrie of South Carolina, who obtained his degree in 1749. The first dissection of the human body in this country was made in New York by Drs. Bard and Middleton in 1750. In 1756 a course of lectures on anatomy and surgery, with demonstrations on the dead body, was given at Newport, Rhode Island, by Dr. William Hunter, a cousin of John Hunter and an Edinburgh graduate. The first regularly organized medical school was established in Philadelphia by Drs. William Shippen and John Morgan, both natives of Philadelphia and graduates of Edinburgh; Dr. Shippen lectured on anatomy and surgery.

The only surgical work by an American author printed in the United States prior to 1800 was the *Plain, Concise Practical Remarks on the Treatment of Wounds and Fractures*, by Dr. John Jones (New York, 1775), reprinted at Philadelphia in the following year with Van Swieten on *The Diseases Incident to Armies and Gunshot Wounds*, the whole forming a small volume which was the manual of the American army surgeons during the Revolutionary War.

Dr. John Jones (1729–91), a native of New York, studied in London under Pott, in Paris under Petit and Le Dran, and in Edinburgh under Monro, was surgeon with troops in the French Colonial War of 1758,

and professor of surgery in King's (now Columbia) College from its commencement in 1767. He is said to have performed the first operation of lithotomy in this country. His book, above referred to, is, in the main, a compend of the teachings of Pott and Le Dran, but contains a few original observations, the most remarkable of which is a case of trephining in delirium occurring eighty days after an apparently slight injury of the head. There was no fracture. After perforating the bone he opened the dura mater, but found nothing, and the result was prompt recovery. At the beginning of the nineteenth century the leading surgeons in the United States were the two Warrens in Boston, Physick in Philadelphia, and Wright Post in New York.

John Warren (1753–1815) was the first professor of anatomy and surgery in the Medical School of Harvard University, which opened in 1783, being the first medical school in New England. He amputated at the shoulder-joint in 1781, extirpated the parotid gland in 1804, and had a great reputation as an operator and teacher, but wrote only a few addresses and journal articles.

His son, Dr. John Collins Warren (1778–1856), studied in London, Edinburgh, and Paris, and returned and joined his father in practice in 1802, becoming adjunct professor in anatomy and surgery in 1806, and professor in 1815. He was a skilful operator, and introduced several new operations, such as excision of the hyoid bone in 1804 and excision of the elbow in 1834. In 1837 he published his *Surgical observations on tumors*, chiefly a collection of cases observed and treated by him—an important work for reference. He was practically the introducer of anæsthesia in surgical operations.

Philip Syng Physick (1768–1837), called by some the "Father of American Surgery," a native of Philadelphia, a pupil and personal friend of John Hunter, who refers to him in his treatise on the blood as having performed many of the experiments referred to, took his medical degree at Edinburgh in 1792, became surgeon of the Pennsylvania Hospital in 1794, and was appointed in 1805 to the chair of surgery established in the University of Pennsylvania in that year. His contributions to practical surgery were numerous, but he wrote nothing, and his views are, for the most part, known through the treatise of his nephew, Dr. Dorsey. Among these contributions may be mentioned the lengthening of Desault's splint for fracture of the femur, which reached only to the crest of the ilium, making it extend from the axilla to below the foot; the internal division of stricture of the urethra; the use of the seton in ununited fracture; his operation for the cure of preternatural anus; and the washing out of the stomach by means of a gum-elastic catheter and a syringe in a case of poisoning.

The first lectures on surgery in Philadelphia were given by Dr. William Shippen (1733–1808), a native of Philadelphia, who studied in Leyden, Edinburgh, and London, and was a special pupil of William Hunter. In 1762 he gave a course of private lectures on anatomy and surgery in Philadelphia, and in 1765 became professor of anatomy and surgery in the Medical Department of the University of Pennsylvania, just established.

Wright Post (1766–1822), a native of New York, studied in London in 1784–86 under Mr. Sheldon, and was appointed professor of surgery

in Columbia College in 1792. He, first in this country, performed the Hunterian operation for aneurism of the femoral in 1796, ligated the subclavian on the outer side of the scaleni in 1817, and in 1813 successfully ligated the external iliac, this being the second operation of this kind. He was a skilled anatomist and a good teacher, but he wrote nothing beyond a few accounts of cases.

The first systematic treatise on surgery published by an American author was the *Elements of surgery* of Dr. Dorsey (Philadelphia, 2 vols. 8vo, 1813), of which a second edition appeared in 1818, and a third in 1823.

John Syng Dorsey (1783–1818), a native of Philadelphia, studied under his uncle, Dr. Physick, and afterward in London and Paris, and in 1807 became adjunct professor of surgery in the University of Pennsylvania. His book was a popular text-book; its chief value is due to the fact that it contains so much of the experience of Dr. Physick. In 1811 Dorsey successfully ligated the external iliac for inguinal aneurism, this being the first case of that operation in the United States.

In 1819, Dr. Physick resigned as professor of surgery to become professor of anatomy, the chair of surgery being filled by Dr. Gibson. Dr. William Gibson (1788–1868) was born in Baltimore, Md. He studied in Edinburgh, where he graduated in 1809, was a pupil of John Bell, and, after his graduation, of Sir Charles Bell in London; professor of surgery in the University of Maryland in 1812, and professor of surgery in the University of Pennsylvania from 1819 to 1855, when he resigned. In 1824 he published his *Institutes and practice of surgery*, which became a popular text-book, the eighth edition having appeared in 1850. He was the first to perform the operation of ligation of the common iliac, which he did in 1812, and successfully to repeat the Cæsarean section on the same patient, which he did in 1837. His reports on rupture of the axillary artery in attempts to reduce old dislocations of the head of the humerus contributed greatly to his reputation. He formed a large and valuable collection of pathological specimens, colored drawings of tumors, etc., some of which are now in the Army Medical Museum at Washington.

The surgeon of the first part of this century whose name is now best known to fame was Dr. Ephraim McDowell (1771–1830), a native of Virginia, who studied in Edinburgh in 1793 under John Bell, who was then giving special attention to diseases of the ovaries. In 1795 he commenced practice at Danville, Kentucky, and soon became the leading physician of the West. In 1809 he performed the first methodical excision of the ovary for the cure of tumor of that organ, and published an account of it, and of two other similar cases, in the *Eclectic Repertory* of Philadelphia in 1817. His reports of the operation attracted little attention at the time, and the few published comments on them were mostly expressions of doubt as to the accuracy of his statements; but the paper of Mr. Lizars, "Observations on the extirpation of the ovaria," in the *Edinburgh Medical and Surgical Journal* in 1824, made them generally known, and although it was long after that date before ovariotomy became recognized as a proper surgical operation, yet the credit due to McDowell for originating it has never since been seriously disputed. He wrote very little and very reluctantly, and was not a teacher

in any school, but his name stands high in the list of the great surgeons of America.

Another distinguished surgeon of this period was Dr. Nathan Smith (1762–1829), a native of Massachusetts, who studied in the Harvard Medical School, in Edinburgh, and in London, and in 1797 founded a medical school in connection with Dartmouth College. In 1813 he became professor of medicine and surgery in Yale College. He was the second person to perform ovariotomy in this country, which he did in July, 1821, without any knowledge of the work of McDowell. He performed the first amputation at the knee-joint in the United States in 1824, first used the trephine in localized inflammation and abscess of the shafts of the long bones, and introduced the manipulation method in the treatment of dislocations of the hip-joint. He wrote little, but an account of his methods and practice is given in a little book entitled *Medical and surgical memoirs*, edited by his son, Nathan R. Smith (published at Baltimore in 1831). It contains an excellent paper on necrosis, a description of an improved apparatus for the treatment of fractures of the femur, remarks on dislocations of the hip, etc.

Some bold operations were performed in these early days by men who wrote nothing and of whom little is known; for example, abdominal section for extra-uterine pregnancy in 1759 by John Bard of New York, and in 1791 by William Baynham; the ligation of the common carotid in 1803 by Mason Fitch Cogswell, and in 1807 by Dr. Amos Twitchell of New Hampshire; the complete excision of the clavicle in 1811 by Dr. Charles McCreary of Kentucky; and the excision of a part of the lower jaw by Dr. Wm. H. Deadrick of Tennessee in 1810. In 1819, Dr. Wm. C. Daniel of Savannah first employed extension by means of a weight in the treatment of fracture of the femur, but did not publish the method until 1829 (*Am. J. Med. Sc.*, 1829, iv. 330). In 1823, McGill of Maryland successfully ligated both carotids; in 1824, Dr. D. L. Rodgers removed nearly the whole of both upper jaws.

Between 1820 and 1850 the prominent surgeons in the large cities were John C. Warren and George Hayward in Boston; Valentine Mott, J. Kearny Rodgers, Willard Parker, Alfred C. Post, and John Watson in New York; W. Gibson (above referred to), J. R. Barton, George McClellan, George W. Norris, and Thomas D. Mütter in Philadelphia; Nathan R. Smith in Baltimore; R. D. Mussey in Cincinnati; and Daniel Brainard in Chicago.

Valentine Mott (1785–1865), a native of Long Island, the son of a physician, studied medicine at Columbia College, obtaining his degree in 1806. He then went to London, became a pupil of Astley Cooper, returned in 1810, and was appointed professor of surgery in Columbia College, and in 1813, when this school was merged in the faculty of the College of Physicians and Surgeons, he retained the chair of surgery. In 1826, with the other professors of the College of Physicians and Surgeons, he resigned his chair, and then with several of his associates founded the Rutgers Medical College; he took the chair of operative surgery in the College of Physicians and Surgeons, which he resigned in 1834 on account of his health. In 1840 he was appointed to the professorship of surgery in the Medical Department of the University of New York. For the next ten years his reputation drew crowds of students from all

parts of the United States. In 1850 he resigned the chair, making another visit to Europe. In the spring of 1852 he was appointed emeritus professor of surgery in the Medical Department of the University of the City of New York, and from that time until his death he delivered an annual course of lectures.

Mott's first contribution to operative surgery was the ligature of the innominate artery in 1818, the patient surviving for a long time, but finally dying of secondary hemorrhage. The case established the practicability, and the propriety in certain cases, of the operation. It was finally successfully performed by Dr. A. W. Smythe of New Orleans in 1864, in which case repeated hemorrhages also occurred, and the vertebral artery was ligated fifty-four days after the first operation. Mott first applied a ligature to the primitive iliac in 1827; in 1828 he entirely removed the clavicle for osteosarcoma; in 1812 he made an original operation for the relief of ankylosis of the lower jaw. At the time when, in 1821, he excised the right half of the lower jaw in a case of tumor he was not aware that a similar operation had been performed in 1810 by Dr. W. H. Deadrick of Tennessee, since no history of the operation was published until 1828. Dupuytren in 1812 had removed a large part of the lower jaw for cancer. Amputation of the hip-joint was performed by Dr. Mott in 1824, and it was for some time supposed that it was the first operation of the kind in America, but it is now known that it was performed by Dr. Walter Brashear of Kentucky in 1806, but no account of his case had ever been published. Speaking of his excision of the clavicle, Dr. Mott called it his "Waterloo operation," since it was performed on the 17th of June, the day before the anniversary of that battle. In 1813, Dr. Charles McCreary had removed the right clavicle for disease of the bone, but it was little enlarged, comparatively isolated, and the operation was a very simple one, being entirely different from the extremely difficult operation performed by Dr. Mott. The patient rapidly recovered. Besides the innominate artery, he tied the subclavian eight times, the primitive carotid fifty-one times, the carotid twice, the common iliac once, the external iliac six times, the internal iliac twice, the femoral fifty-seven times, and the popliteal ten times. His writings consist mainly of reports of cases and operations for periodicals.

J. Kearny Rodgers (1793–1851), a native of New York, was a pupil of Dr. Wright Post and graduated at the College of Physicians and Surgeons in 1816. He studied in London under Astley Cooper, became surgeon of the New York Hospital in 1822, and tied the left subclavian artery within the scaleni for aneurism in 1845, the first time this operation had been performed: it was unsuccessful. The first successful operation of this kind was by Dr. Halsted of Baltimore in 1892. Dr. Rodgers successfully wired an ununited fracture of the humerus in 1827 after excision had been unsuccessfully performed, perhaps the first operation of this kind, and made a cuneiform osteotomy in ankylosis of the hip in 1840. He wrote only a few papers for periodicals.

Willard Parker (1800–84), a native of New Hampshire, studied under John C. Warren, and graduated at Harvard in 1830. He was for a short time professor of surgery in Berkshire Medical College, and was a colleague of Gross in Cincinnati. In 1839 he became professor

of surgery in the College of Physicians and Surgeons, surgeon of Bellevue Hospital in 1845, and surgeon of the New York Hospital in 1856. He was an excellent teacher and operator and greatly beloved by his pupils, who constituted his best contributions to surgery. He was the first operator for strabismus in this country.

Alfred C. Post (1805–85), a native of New York and a nephew of Dr. Wright Post, graduated in medicine at the College of Physicians and Surgeons in New York in 1827, and continued his studies in Paris, Berlin, and Edinburgh. He was one of the founders of the Medical Department of the University of the City of New York in 1851, in which he was professor of surgery and pathological anatomy. He wrote no systematic treatise, but contributed numerous cases to the journals, and was specially skilled in plastic surgery.

John Watson (1807–63), a native of Ireland, came with his parents to America in 1810, and graduated in 1832. He became surgeon of the New York Hospital in 1838, where he first introduced regular clinical instruction in surgery, though Dr. Alexander H. Stevens had previously delivered occasional clinical lectures. He contributed many cases to journals, but wrote no systematic treatises. He collected what was at that time the most valuable private medical library in this country, the greater part of which, after his death, was left to the New York Hospital Library.

John Rhea Barton (1794–1871), a native of Lancaster, Pa., graduated at the University of Pennsylvania in 1818, and became surgeon of the Pennsylvania Hospital. His name is associated with a form of fracture of the lower end of the radius, with a special form of bandage for fracture of the jaw, and with osteotomy for ankylosis, which he first performed in 1826. In 1834 he wired a fractured patella.

George McClellan (1796–1847) was a native of Connecticut and a pupil of Dr. Dorsey, graduating at the University of Pennsylvania in 1819. He founded the Jefferson Medical College in 1824, in which he was professor of surgery until 1838. He excised the body of the lower jaw in 1823, excised the parotid gland for tumors, and was a bold and showy operator. After his death his book on *Principles and practice of surgery* was published in 1848: it is noteworthy only for the very excellent description of shock which it contains.

George Washington Norris (1808–75) was a native of Philadelphia, and graduated at the University of Pennsylvania in 1830. After two years' service in the Pennsylvania Hospital he went to Paris, and studied under Dupuytren, Velpeau, and Roux. He became surgeon to the Pennsylvania Hospital and professor of clinical surgery in the University of Pennsylvania. His name is well known in medical literature from the extremely valuable statistical contributions to practical surgery which he published in the *American Journal of the Medical Sciences* between 1828 and 1854. They rank among the best work of this kind which has ever been done in any country, and his results are quoted in all subsequent treatises upon the subjects upon which he wrote.

Thomas Dent Mütter (1811–59), a native of Virginia, graduated at the University of Pennsylvania, after which he studied medicine in Paris. He became professor of medicine in the Jefferson Medical College in 1841, and is celebrated for his plastic operations for the cure of

deformities resulting from burns. He gave his museum to the College of Physicians of Philadelphia, with thirty thousand dollars for its maintenance and the endowment of a lectureship. In this connection may be mentioned:

William E. Horner (1793–1853), a native of Virginia, who became a surgeon in the hospital department of the army in 1813, when he was twenty years old and before he had graduated. He became professor of anatomy in the University of Pennsylvania in 1831, succeeding Dr. Dorsey. His name is connected with the Wistar and Horner Museum, which he bequeathed to the university, and also with the muscle which he named the "tensor tarsi." His contributions to surgery are to be found in papers in the *American Journal of the Medical Sciences*.

R. D. Mussey (1780–1866), a native of New Hampshire, studied medicine under Dr. Nathan Smith, and graduated at the University of Pennsylvania in 1809. He was professor of the theory and practice of medicine at Dartmouth, 1814; professor of anatomy and surgery in the same school, 1819; professor of surgery in the Medical College of Ohio at Cincinnati in 1838; and professor of surgery in the Miami Medical College in Cincinnati in 1852. He was a bold operator, and first tied both carotid arteries in 1827 for a large bleeding tumor of the head, and removed the scapula and clavicle for tumor following amputation at the shoulder-joint. His only contributions to surgical literature were in the shape of reports of cases in the journals.

Daniel Brainard (1812–66), a native of Western New York, graduated at the Jefferson Medical College, Philadelphia, in 1834. He successfully amputated at the hip-joint in Chicago in 1838, which established his reputation, and in 1854 published an excellent essay on the treatment of ununited fractures. He was the founder of Rush Medical College.

One of the most celebrated surgeons of the West of this period was Benjamin W. Dudley (1785–1870), a native of Virginia, who graduated at the University of Pennsylvania in 1806, after which he studied in Paris and London, returning to Lexington in 1814, and became professor of anatomy and surgery in the Medical Department of the Transylvania University in 1817. His reputation rested mainly upon his operations for lithotomy, which he performed two hundred and twenty-five times with almost unparalleled success. He wrote nothing except a few short essays, the first of which, *Observations on injuries of the head* [including cases of trephining for epilepsy], was published in the first number of the *Transylvania Journal of Medicine* in 1828, and is a very important paper in the history of this operation.

We now come to an epoch in the history of surgery. On November 3, 1846, Dr. Henry J. Bigelow read before the American Academy of Arts and Sciences an abstract of a paper which was published in full in the *Boston Medical and Surgical Journal* of November 18, 1846, under the title "Insensibility during surgical operations produced by inhalation," which was the first definite account of the method of production of satisfactory anæsthesia in surgical operations. Writers of the thirteenth and fourteenth centuries had described the inhalation of narcotic vapors from certain plants for this purpose. Sir Humphry Davy had suggested in 1800 that "nitrous oxide may probably be used with advantage in surgical operations." Mr. Hickman, a London surgeon,

had written in 1828 a letter to King Charles X. (which letter was laid before the Academy of Medicine of Paris), in which he said that he had discovered the means of performing the most troublesome operations without pain by producing insensibility by the introduction of certain gases into the lungs (*Archiv. gén. de méd.*, 1st ser. xviii. p. 453). Dr. Crawford W. Long of Athens, Ga., had produced anæsthesia by ether in 1842 for the operation of removing small tumors, but had not published the results, when Dr. Warren allowed a dentist, Dr. Morton, to give ether to produce insensibility while he performed a small operation in the Massachusetts General Hospital.

It is to Warren, Hayward, and Bigelow that the surgical world is indebted mainly for a sufficient, general, and safe method of anæsthesia. Morton wanted to patent his method, which was not a thoroughly safe one until modified by Bigelow, and little credit is due to him or to Wells or Jackson for the part which they then played in the business. The statements of Dr. Bigelow were readily accepted by surgeons, and early in 1847 anæsthesia was in general use throughout the civilized world.

Nothing like it had been known before, and there has been little improvement in it since, for chloroform, though more convenient for use, is decidedly more dangerous than ether in many cases. Most of the great operations had been devised and performed by a few skilled operators before the introduction of anæsthesia, but the performance was not in the deliberate, careful manner which is now well recognized as characterizing the best surgery, especially in these days of asepsis and antisepsis. The influence of anæsthesia upon surgical diagnosis has been almost as great as upon methods of operation, for with its aid it is possible to explore the interior of the body in ways that would be impossible without it. With its aid the recent graduate undertakes operations which he would not dream of trying without it: it has done away with the need for some of the most special qualifications which formerly were thought to be, if not indispensable, at least of great importance to the operator.

Henry Jacob Bigelow (1816–90), a native of Boston, took his medical degree in 1841, after which he spent three years in Europe, most of the time in Paris. In 1845 he was appointed instructor of surgery at the Tremont Street Medical School. In 1846 he was made surgeon to the Massachusetts General Hospital, and in 1849 was appointed professor of surgery in the Harvard Medical School, the two chairs of surgery and clinical surgery, previously held by Dr. J. C. Warren and Dr. George Hayward, being united. He performed the first excision of the hip-joint in this country in 1852, and first explained the mechanism of the ileo-femoral ligament and its importance in reducing dislocations of the hip-joint. His chief contribution to surgery was his operation of litholapaxy, which has effected a great change in the treatment of vesical calculus. He was a graceful and dexterous operator, a clear and epigrammatic teacher, and the leading surgeon in New England until he retired in 1882.

The number of American surgeons who have become known as inventors, teachers, or writers since 1850 is very large, and only a brief notice can be given of the most prominent. In New York we have had William H. Van Buren (1819–83), who studied in Paris, was an assistant surgeon in the army for four years, in 1845 joined Mott in

clinical teaching, became professor of anatomy in 1852, and professor of surgery in the Bellevue Medical College in 1868. His *Contributions to practical surgery* appeared in 1865, and his work on *Diseases of the genito-urinary system* in 1874.

Gurdon Buck (1807–77), surgeon of the New York Hospital in 1837, and of St. Luke's in 1858, made valuable contributions to surgery in the method of treating fractures of the thigh by weight and pulley, in the plastic surgery of the face, and in the treatment of ankylosis of the knee.

James R. Wood (1816–82), the first to introduce clinical teaching in Bellevue Hospital, and one of the founders of Bellevue Medical College, was a bold operator and a very popular teacher. He removed the entire lower jaw in a case of phosphorus-necrosis, leaving the periosteum from which a new jaw was formed; excised Meckel's ganglion with the superior maxillary branch of the fifth pair; and was one of the first in America to perform excision of the shoulder- and elbow-joints.

Frank H. Hamilton (1813–66), a native of Vermont, graduated in Philadelphia in 1833; became professor of surgery in Buffalo in 1844, and in the Bellevue Medical College in New York in 1862. He published his *Practical treatise on fractures and dislocations* (Philadelphia, 1860) and his *Practical treatise on military surgery* (1861; 2d ed. 1865).

Alden March (1795–1869) settled in Albany in 1820 after graduating at Brown University, Rhode Island, and commenced lecturing on anatomy in 1821, being the first lecturer in that city. He was professor of surgery in the Albany Medical College in 1838, and gave one of the first surgical clinics in this country. He made valuable investigations in hip-joint disease, and performed a large number of surgical operations, including sixty-five amputations through the thigh and eleven excisions of the lower jaw.

Henry Berton Sands (1830–88) graduated from the College of Physicians and Surgeons in New York in 1854; studied in Paris; and on his return became professor of anatomy, and then of surgery. He was surgeon to the Bellevue and New York Hospitals and to the Roosevelt Hospital, and in the latter part of his life was the leading surgeon in New York City. He was the first to operate in peritonitis due to perforation of the appendix.

Here also may be mentioned J. Marion Sims (1813–83), a native of South Carolina, who commenced practice in Montgomery, Alabama, and there devised his mode of operating for vesico-vaginal fistula; he came to New York in 1853, and became the founder of modern gynæcology.

The Philadelphia surgeons of this period who have finished their work are Gross (father and son), Agnew, Pancoast, and Smith.

Samuel D. Gross (1805–84), a native of Pennsylvania and a graduate of the Jefferson Medical College in 1828, after filling various chairs in Western schools and in New York accepted the chair of surgery in the Jefferson Medical School in 1865, from which he retired in 1882. He was a man of strong personality and great influence, an incessant worker, a voluminous writer, an excellent teacher, and one of the most distinguished surgeons of his time. He wrote the first systematic treatise on pathological anatomy by an American author, made original experiments on wounds of the intestines, published

valuable monographs on diseases of the bladder (1851; 2d ed. 1855), on foreign bodies in the air-passages (1854), and a system of surgery in two large volumes (1859; 6th ed. 1882), which is an important book of reference.

His son, Samuel W. Gross (1837–89), graduated at the Jefferson Medical College in 1857. On the outbreak of the Civil War he became a surgeon of volunteers, acting as medical director in various departments until 1865. In 1882, on the retirement of his father, he was elected one of the professors of surgery in Jefferson Medical College. He made numerous contributions to surgical literature in the journals, published a treatise on Tumors of the mammary glands in 1882, a treatise on Impotence and sterility in 1881, and assisted his father in the preparation of the various editions of his System of Surgery. He was a bold yet careful operator and an earnest and eloquent lecturer.

Joseph Pancoast (1805–82), a native of New Jersey, graduated at the University of Pennsylvania in 1828. He began teaching practical anatomy and surgery in 1831. In 1838 he was elected professor of surgery in the Jefferson Medical College; in 1847, professor of anatomy in the same college. He published his *Treatise on operative surgery* in 1844 (3d ed. 1852). He was distinguished for his operations in plastic surgery, especially for exstrophy of the bladder; devised the operation of section of the third branch of the fifth pair of nerves at its issue from the base of the skull, and of the second branch of the fifth pair at the same place; was a skilled anatomist, a dexterous operator, and a popular clinical teacher.

Henry H. Smith (1815–90), a native of Philadelphia, graduated at the University of Pennsylvania in 1837, after which he studied in London and Paris. He became professor of surgery in the University of Pennsylvania in 1855, and resigned in 1871. His *System of operative surgery*, published in 1853 (2d ed. in 1856), contains a valuable history of surgery in the United States, with an index of the principal contributions of American writers on subjects connected with operative surgery down to the year 1854.

Francis Fontaine Maury (1840–79), a native of Kentucky, graduated at Jefferson Medical College in 1862; performed the first operation of gastrotomy in this country, excision of the brachial plexus for painful neuroma, operation for exstrophy of the bladder, and two operations for extirpation of the thyroid gland. He was surgeon of the Philadelphia Hospital.

Dr. D. Hayes Agnew (1818–92), a native of Pennsylvania, graduated at the University of Pennsylvania in 1838. In 1852 he became the head of the Philadelphia School of Anatomy, to which he soon added a school of operative surgery; in 1863 he left this to become demonstrator of anatomy in the University of Pennsylvania, in which he became professor of clinical surgery in 1878 and professor of surgery in 1871. A highly-skilled anatomist, an unusually dexterous operator, and a keen, shrewd diagnostician, he acquired an immense practical experience in all forms of surgical affections and treatment, which he embodied in his treatise on the *Principles and practice of surgery*, published in three large volumes in 1878–83, and again in a second edition in 1889. He was one of the few great surgeons who have continued to

practise medicine as well as surgery until the end of their career, and he did this because he believed it made him a better surgeon.

J. L. Atlee (1799–1885), a native of Lancaster, Pa., graduated at the University of Pennsylvania in 1820, and practised at Lancaster throughout his life. In 1843 he revived the operation of ovariotomy, and with his brother established it on a firm basis. He was the first successfully to remove both ovaries at one operation.

Washington L. Atlee, his brother (1808–78), was a pupil of George McClellan, and performed his first operations for ovariotomy in 1844. This operation he performed three hundred and eighty-seven times, and had more influence in popularizing it than any other man in this country. His most important contribution to literature is on the diagnosis of ovarian tumors, published in 1873. He was also celebrated as an operator for the removal of uterine tumors.

Jonathan Knight (1789–1864) studied at the University of Pennsylvania, and became professor of anatomy and physiology in the Medical Institution of Yale College when it was organized in 1813. In 1838 he became professor of surgery, and held the chair to the end of his life.

Paul F. Eve (1806–77), a native of Georgia, graduated from the University of Pennsylvania in 1828. He studied several years in Europe, was a volunteer surgeon in the Polish Rebellion of 1831, and became professor of surgery in the Medical College of Georgia in 1832, in Louisville University in 1849, in the Nashville University in 1850, in the Missouri Medical College of St. Louis in 1868, and professor of operative and clinical surgery in the University of Nashville from 1870 to the date of his death. He published *A collection of remarkable cases in surgery* (Philadelphia, 1857)—a most useful and interesting work, and it is highly desirable that a similar collection should be made for the latter half of this century.

George C. Blackman (1819–71), a native of Connecticut, graduated in medicine at the College of Physicians and Surgeons, New York, in 1840, and for the next ten or fifteen years was engaged in study in Great Britain and in France, and as surgeon of an Atlantic packet-ship; in 1855 he became professor of surgery in the Medical College of Ohio. He was a skilful diagnostician and anatomist, a bold surgeon, an excellent clinical teacher, and thoroughly at home in surgical literature. He contributed largely to periodicals, re-edited Mott's edition of Velpeau, and translated the work of Vidal on *Venereal diseases*, but left no monograph or systematic treatise.

Charles Pope (1818–70), professor of surgery in St. Louis, Mo., in 1847, was distinguished as an operator and teacher, but wrote very little.

Elias Samuel Cooper (1823–62), a native of Ohio, studied medicine in Connecticut when very young; began practice at nineteen years of age, soon after which he excised a large portion of the lower jaw, and at the age of twenty-three opened a dissecting-room in Peoria, Ill., and gave lectures on anatomy. In 1855 he removed to San Francisco, and in 1858 was one of the founders of the Medical Department of the University of the Pacific, in which he became professor of anatomy and surgery. He performed a number of the greater surgical operations, twice ligated the innominate artery, twice performed Cæsarean section, and repeatedly

operated for ovarian tumors. One of his most celebrated operations was the removal of a piece of iron an inch long and three-quarters of an inch thick, which the explosion of a gun-barrel had driven into the chest beneath and behind the heart, and which had remained there over two months. His contributions to the literature of surgery are found entirely in periodicals.

Robert Nelson (1794–1873), a native of Canada, became distinguished as a surgeon in Montreal, and especially as a lithotomist; implicated in the rebellion of 1837, he came to the United States, for a short time filled the chair of anatomy and surgery at Castleton, Vt., and Pittsfield, Mass.; went to California in 1849, and finally settled in New York. He is the author of a pamphlet, *Gastrotomy for the removal of non-malignant tumors from the abdominal cavity* (New York, 1864), and of papers in the journals, especially in the *Northern Lancet*, of which he was the editor from 1850 to 1856.

John T. Hodgen (1824–82), a native of Illinois, professor of anatomy in the Missouri Medical College in 1852, and professor of clinical and military surgery in 1872, made valuable contributions to methods of treatment of fractures, and his splint is well known.

George Alexander Otis (1830–81) was a native of Boston, and graduated in medicine at the University of Pennsylvania in 1851. He studied in Paris, entered the army in 1861, was curator of the Army Medical Museum, and wrote the first two surgical volumes of the *Medical and surgical history of the war of the rebellion*, using the vast material in a thoroughly scientific manner.

Moses Gunn (1822–87), a native of New York, of Scotch descent, settled at Ann Arbor, Mich., became professor of anatomy and surgery in 1850, and professor of surgery in Rush Medical College in 1867, succeeding Brainard. He was a skilled anatomist, a popular teacher, and wrote a valuable paper on reduction of dislocations by manipulation.

John M. Carnochan (1817–87), a native of Savannah, Ga., a pupil of Valentine Mott, a surgeon in New York City, was a daring operator. He excised the entire lower jaw in 1851 and in 1864, removed Meckel's ganglion and the superior maxillary nerve in 1856, and ligated the femoral for elephantiasis in 1851. Besides journal articles he was the author of *A treatise on . . . . congenital dislocations of the head of the femur* (New York, 1850, 8vo) and *Contributions to operative surgery and surgical pathology* (New York, 1877–83, 4to).

Robert Alexander Kinloch (1826–91), a native of Charleston, graduated in medicine from the University of Pennsylvania in 1848, after which he studied in London, Paris, and Edinburgh. During the Civil War he was medical director on the staffs of Generals Lee, Pemberton, and Beauregard. In 1867 he became professor of materia medica and therapeutics in the Medical College of the State of South Carolina, and soon afterward professor of surgery, which position he held to the time of his death. He was the most prominent surgeon in his State, and was the first in this country successfully to excise the knee-joint for chronic disease and to treat fracture of the lower jaw by wiring the fragments. He was also the first surgeon to open the abdomen in cases of gunshot wounds in which there is no protrusion of the viscera. His contributions to surgical literature were entirely to medical periodicals.

Other surgeons well known in their own States were George Hayward (1791–1868), professor of surgery in the Harvard Medical School, who published some valuable surgical reports in journals and in a volume in 1865; Jacob Randolph (1796–1848), surgeon of the Pennsylvania Hospital, who introduced lithotrity in America; Horace A. Ackley (1812–59), professor of surgery at Cleveland, Ohio, 1843–56; Ely Geddings (1799–1878), professor of surgery in Charleston, S. C., the outlines of whose lectures were published in 1858; John Neill (1819–80), professor of surgery in the Philadelphia College; Ernst Krackowizer (1821–75), a native of Upper Austria, who came to New York in 1850, and was surgeon of the Brooklyn City Hospital; Julius F. Miner (1823–86), professor of surgery in Buffalo; Joseph C. Hutchinson (1827–87), professor of surgery in Brooklyn; and Josiah C. Nott (1804–73), professor of surgery at Mobile, but better known as a writer on ethnology.

The history of surgery in the United States has been told by Gross (*Am. Jour. Med. Sc.*, N. S., lxxi. 1876, 431), and its triumphs in the way of first operations have been set forth by Dr. Dennis (*Medical Record of New York*, 1892, xlii. 637–648), and to these papers the reader is referred for details which there is not space here to give.

In addition to anæsthesia, ovariotomy, and the foundation of modern gynæcology, American surgeons have contributed much to the art in the way of perfecting apparatus for the treatment of fractures by extension; of reduction of dislocations by manipulation; of the treatment of diseases of the hip and spine; of the ligation of large blood-vessels; of the removal of tumors; of the surgery of the brain, spinal cord, mouth, jaws, kidney, liver, and urinary organs. It is true that the scattered, unreported "first cases" of some of the great operations by early American physicians must be considered as entitling the individual to praise for his boldness or ingenuity rather than as "contributions to surgery," because it is not until such procedures have been made known to the profession and become a part of surgical literature or teaching that they have become useful; but from the beginning of the history of the art we find that the majority of the "first operations" of all kinds have been made, not by distinguished professors and famous authors, but by men who were neither teachers nor authors, and the names of many of whom are unknown to this day. This is true of amputations, lithotomy, herniotomy, trephining, excision of the breast, ligation of a wounded artery, Cæsarean section, hysterectomy, ovariotomy, and of the invention of many of the primitive forms of some of the most important instruments of the present day. "Les petits prophets," as Verneuil styles them, are worthy of all honor, and one of the objects of a history of surgery is to keep their names at least from being forgotten. American surgeons have contributed at least a fair share to the common stock of knowledge in the past, and it seems probable that they will do still more in the near future. They have been, for the most part, "practical men:" it is only within the last twenty years that the scientific problems of surgical pathology have been the subject of experiment and study in this country, but it is quite probable that the John Hunter or Joseph Lister of America is now busy with his preliminary work.

A most important step in the progress of medicine was made when physicians and surgeons began to form associations and societies for the purpose of mutual improvement and for the publication of papers read before them, rather than for guarding trade interests; and the transactions of such societies form a most valuable section of medical literature. The first of these societies which was devoted specially to surgery, and whose publications were important, was the Académie royale de chirurgie, the memoirs of which appeared in 5 quarto volumes (Paris, 1743–74, and again in 15 vols. 12mo, Paris, 1771–87, in 5 vols. 8vo, Paris, 1819, and in 3 vols. 8vo, Paris, 1838).

The *Mémoires* and *Bulletins* of the Société de Chirurgie de Paris, published from 1847 to the present time, and forming 52 volumes; the *Verhandlungen* of the Deutsche Gesellschaft für Chirurgie, in 35 volumes, 1872–93; the *Transactions* of the American Surgical Association, in 10 volumes, 1883–92; and the *Procés-verbaux, mémoires, etc.* of the Congrès français de Chirurgie,—are the most important of the purely surgical publications of this class in the present century. No surgical association publishing professional reports has existed in Great Britain, the Royal Colleges of Surgeons of Edinburgh, of England, and in Ireland not having undertaken this line of work.

The following is a list of the most important journals devoted especially to general surgery, arranged in order of date:

Chirurgische Bibliothek, von August Gottlieb Richter, 1771–96, 8vo, Göttingen u. Gotha.

Journal de Chirurgie, par Pierre-Joseph Desault, 1791–92, 8vo, Paris.

Bibliothek für die Chirurgie, Hrsg. von C. J. M. Langenbeck, 1805–13, 8vo, Göttingen.

Neue Bibliothek für die Chirurgie und Ophthalmologie, Hrsg. von C. J. M. Langenbeck, 1815–28, 8vo, Hannover.

Journal der Chirurgie und Augen-Heilkunde, Hrsg. von C. F. Graefe und Ph. von Walther (quarterly), 1820–50, 8vo, Berlin.

Giornale di Chirurgia-pratica, compilato dal dott. G. Canella, 1825–29, 8vo, Trento.

Annales de la chirurgie française et étrangère, publiées par MM. Bégin, Marchal, Velpeau et Vidal, 1841–45, 8vo, Paris.

Journal de Chirurgie, par M. Malgaigne, 1843–46, 8vo, Paris.

Archiv für klinische Chirurgie, Hrsg. von Dr. B. von Langenbeck, red. von Billroth und Gurlt, 1860–94, 8vo, Berlin.

Deutsche Zeitschrift für Chirurgie, Hrsg. von Bardeleben (et al.); red. von C. Hueter und A. Lücke, 1872–94, 8vo, Leipzig.

Centralblatt für Chirurgie, Hrsg. von L. von Lesser, M. Schede, H. Tillmanns (weekly), 1874–94, 8vo, Leipzig.

Revue de chirurgie, rédacteurs en chef, MM. Nicaise et F. Terrier; directeurs, MM. Ollier et Verneuil, 1881–89, 8vo, Paris.

Annals of Surgery, a monthly review of surgical science and practice, edited by L. S. Pilcher and C. B. Keetley, 1885–94, 8vo, St. Louis.

Archives of Surgery, by J. Hutchinson (quarterly), 1889–94, 8vo, London.

SURGICAL PATHOLOGY, INCLUDING INFLAMMATION AND THE REPAIR OF WOUNDS.

By W. T. COUNCILMAN, M. D.

I. INFLAMMATION.

Inflammation is one of the most important subjects in medicine and surgery, and one of the most difficult to comprehend. It has played an important part in the history of medicine, and most of the theories of disease formerly held were more or less based on conceptions of its nature. It is only in comparatively recent years, when patient observation and experiment have taken the place of theory, that the true nature of inflammation has been better understood.

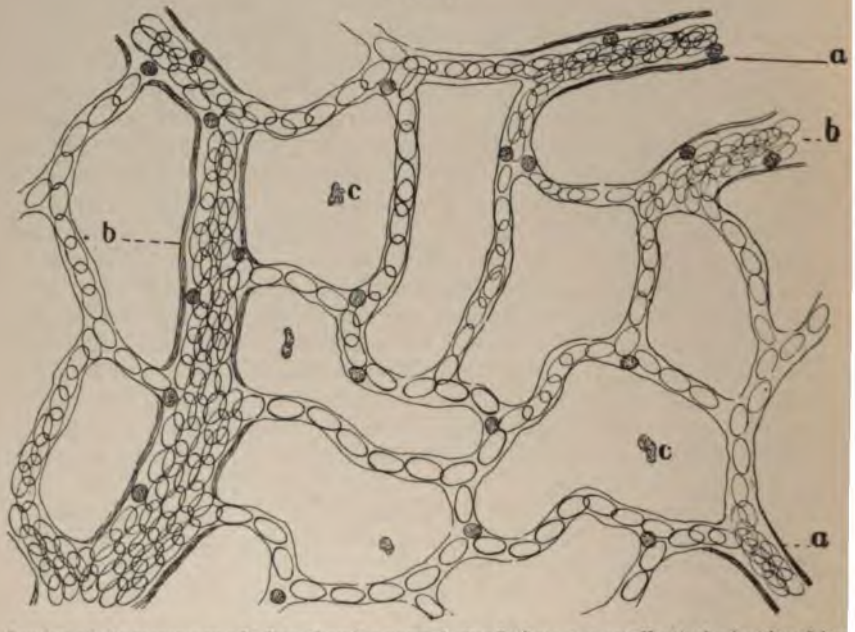
Were we to take up all the phenomena of inflammation and study each process fully, it would practically include all pathology. So extensive is the subject, and so intimately is it related to other pathological processes, that it has recently been proposed to abolish the term "inflammation" entirely, and to consider the various phenomena under other divisions of pathology where they naturally belong. The phenomena of inflammation are closely connected with the pathology of the circulation, with the degeneration and regeneration of tissue, with the action of bacteria, with injuries, etc. Still, it is well to have some one term to include the tissue-changes following an injury, and we may define inflammation as the sum of the phenomena which take place in the tissue as the effect of an injury. The object of these various phenomena is to overcome or to diminish the effects of the injury. The study of inflammatory processes may be well begun with the changes which take place in the blood-vessels, and in the connective tissue, which everywhere stands in close connection with these.

It will be well to consider the character of the normal connective tissue and the relations which it has with the circulation. The connective tissue in the body serves the important function of binding together the various parts, and acts as a support to the blood-vessels, which, with this tissue, grow into the various structures in the course of development. The connective tissue varies in its structure. It is composed of cells and of fibres which differ in their physical and chemical qualities. In places the fibres are loosely connected together, as in the areolar tissues, and in places they are compacted in close bundles, as in the tendon. The number of blood-vessels in this tissue varies greatly in the different parts of the body, the number standing in exact relation to the importance of the adjacent epithelial structures. Most of the blood-vessels in the connective tissue do not serve the purpose of its

nutrition, the tissue simply serving as a bed for their support. Where the blood-vessels in the connective tissue are for the nutrition of this alone, they are not found in such large numbers. The nutrition of the tissue is carried on by means of the lymph which passes through the walls of the vessels and circulates through the tissue. In some places there are no definite tracks taken by the lymph. In the subcutaneous areolar tissue there is a loose meshwork of fibres containing a variable number of cells, and the tissue is simply saturated with the fluids. In other places, as in the cornea, the fibres of the tissue are compacted into a dense mass containing channels and spaces in which the cells lie and in which the lymph circulates. In still other places the nutrition seems to take place through the cells alone. In the cartilage, for instance, there is a compact intercellular substance, with no spaces either around or between the cells, so that the nutrition of this tissue is probably kept up from cell to cell.

The vascular phenomena which take place in inflammation can be directly studied under the microscope in a transparent part, as in the web of the frog's foot or in the mesentery (Fig. 1). The mesentery of

FIG. 1.

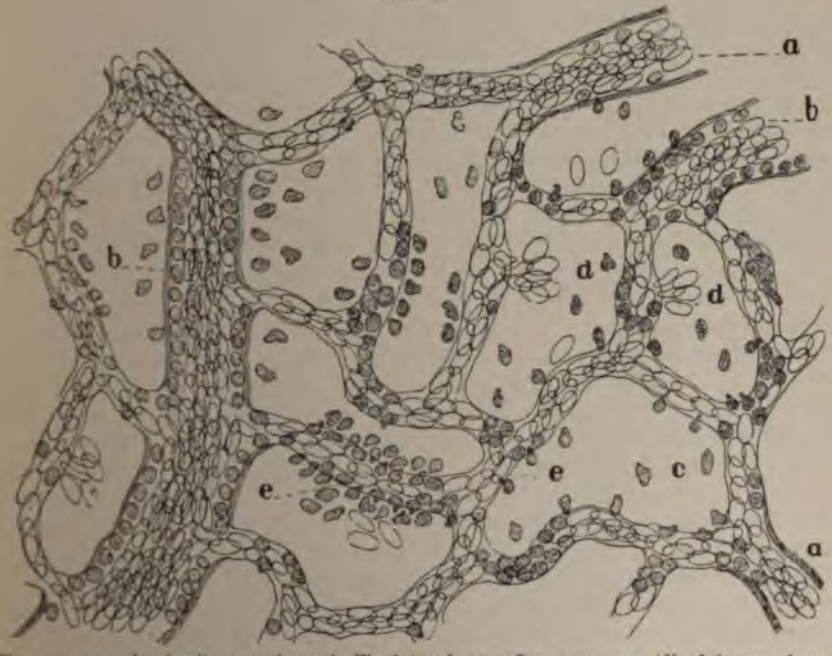


Portion of the mesentery of a frog, showing normal circulation: *a*, *a*, small arteries just breaking up into capillaries; *b*, *b*, small veins; *c*, *c*, wandering cells (leucocytes in connective tissue).

the frog is a thin tissue which is covered on the outside by a single layer of flat endothelial cells, beneath which is a layer of rather firmly-interwoven connective-tissue fibres, with numerous blood-vessels, nerves, and lymphatics. The arteries and veins in the mesentery are relatively more numerous than the capillaries, because the tissue mainly serves to support the vessels passing from its root to the intestine. Under the microscope the

normal circulation can be studied and the gradual development of inflammatory changes observed. In the various sorts of vessels differences in the character of the circulation may be recognized. In the arteries there is an evident pulsating stream. At each contraction of the heart the blood is swept along so rapidly that it is not possible to recognize the individual corpuscles. In the diastole the stream becomes slower and we can see the individual corpuscles. In the veins the movement of the blood is a continuous one, and is slower than in the arteries. In the capillaries the movement of the blood is slow and regular. Neither in the veins nor in the arteries do the red blood-corpuscles completely fill the vessel. We recognize a central core composed entirely of masses of red blood-corpuscles, and between this and the wall of the vessel is a colorless zone which contains no red blood-corpuscles, and in which here and there single white corpuscles roll along. In the frog's web it is necessary to injure the tissue either by chemical or mechanical violence to produce inflammation, while the mere exposure of the mesentery to the air produces sufficient injury to bring about all of the phenomena.

FIG. 2.



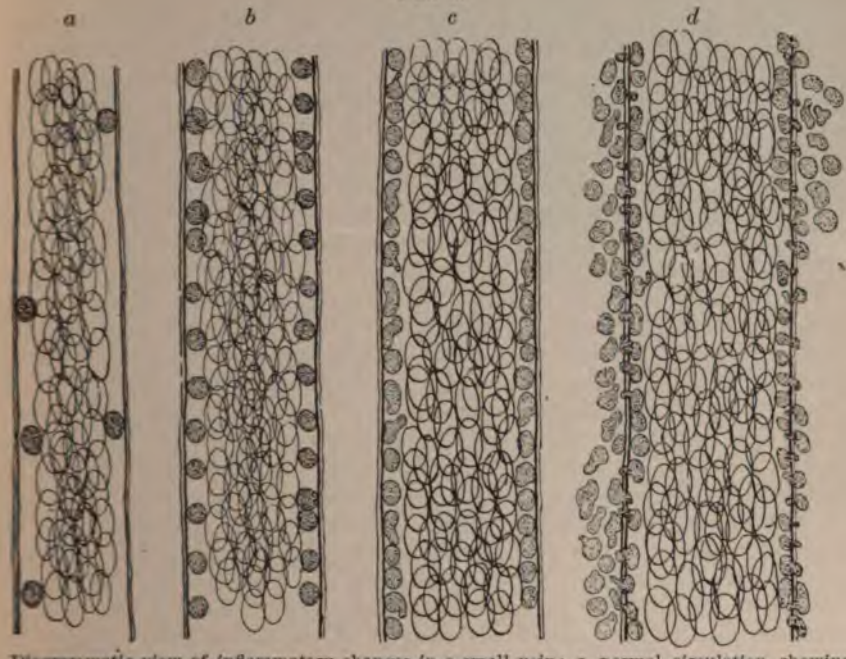
The same vascular territory as shown in Fig. 1, two hours after exposure. All of the vessels are dilated. The leucocytes are more numerous; they have collected along the walls of the vessels, and in several places are passing through: at *d* diapedesis of the red corpuscles is shown, and at *e* emigration of leucocytes. There are large numbers of leucocytes in the connective tissue.

If care be taken in placing the mesentery beneath the microscope to produce as little injury as possible, all of the phenomena will take place so gradually that the single steps can be easily followed. At first no changes at all are seen in the circulation. Under some circumstances the first change seen is a contraction of the small arteries. This is always tem-

porary, and is often not observed, and in any case it quickly gives place to dilatation. The dilatation of the arteries is accompanied by a great rapidity of circulation. The blood flows through all of the vessels with increased speed. Even in the capillaries the flow is sometimes so rapid that the individual corpuscles cannot be seen. Vessels appear which were previously invisible from their small size. The veins take part in the dilatation, and the flow in them is also more rapid. This is the stage of active arterial hyperæmia. There is more blood brought to the part by the dilated arteries; more passes through and is carried off by the veins.

This condition of the circulation soon gives place to another (Fig. 2). The dilatation of the blood-vessels continues, but the current becomes slower. The circulation in the dilated capillaries may become so slow that they become filled with red blood-corpuscles, and appear as red lines running through the tissue. The slowing of the current and dilatation of the vessels are much more evident in the veins than in the capillaries, and a marked change takes place in the plasma-zone of the veins. In the normal circulation the white corpuscles are confined to this zone, and they roll along the wall in the clear fluid. These corpuscles gradually increase in number, and the entire plasma-zone of the vein becomes filled with them. Although the blood-current of the vein is slow, the progress of the white corpuscles in the plasma-zone does not keep pace with that of the red corpuscles in the centre. They will frequently cling for a time to the wall of the vessel, and then again be swept away by the current. Numbers of them remain, and finally the wall of the vessel becomes lined with them. These corpuscles in the plasma-zone undergo rapid amœboid changes, and may move from place to place along the vessel. Some of them become apparently fixed to the wall of the vessel, and then a striking phenomenon takes place. A small bud appears on the outside of the vessel opposite the point at which a white corpuscle adheres. This projecting bud gradually becomes larger and at the same time that part of the corpuscle inside the vessel becomes smaller, and after a variable length of time the corpuscle passes entirely through the wall of the vessel. This passage of the white corpuscles through the walls of the vessels is spoken of as emigration, and when it once begins it goes on with considerable rapidity, until finally the tissue outside of the blood-vessels becomes filled with these corpuscles. They accumulate in the tissue and lie in the meshes between the fibrils and in the lymph-spaces (Figs. 3 and 4). The emigration is not always easily observed. To see it under the best circumstances vigorous frogs should be selected and care taken in spreading the membrane out to produce as little injury as possible. It is much more easily seen in the vessels of the bladder than in those of the mesentery. The bladder can be filled with salt solution, turned out through the rectum and directly observed. Sometimes it takes more than an hour for the corpuscle to pass through the wall of the vessel. The white corpuscles accumulate in the dilated capillaries, but to a much greater extent in the veins. Both the red and the white corpuscles pass through the walls of the capillaries. The red corpuscles may also pass through the walls of the veins, but this is comparatively rare. This passage of the red corpuscles through the walls of the vessels is called diapedesis. They pass through

FIG. 3.

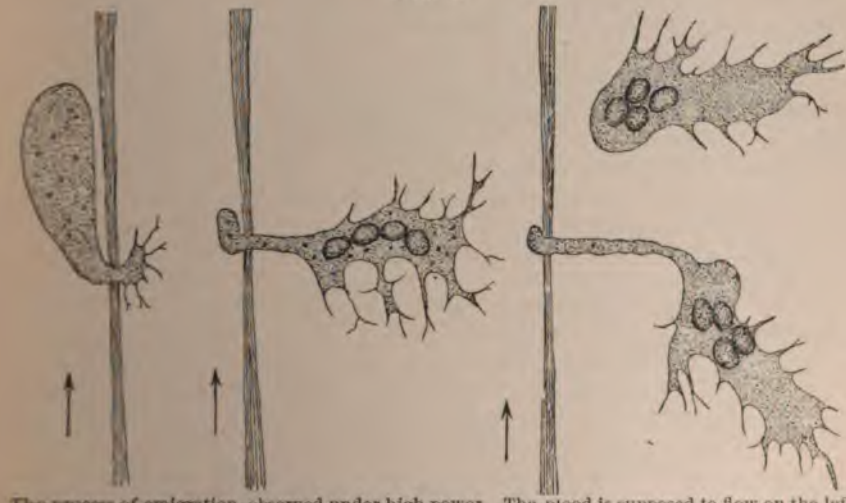


Diagrammatic view of inflammatory changes in a small vein: *a*, normal circulation, showing plasma-zone; *b*, *c*, *d*, successive changes, showing dilatation, accumulation of leucocytes, and emigration.

the walls of the capillaries in much greater numbers than the white corpuscles.

Not only do the white and red corpuscles pass through the walls of

FIG. 4.



The process of emigration, observed under high power. The blood is supposed to flow on the left of the line in the direction indicated by the arrow. The tissue is on the right. × 1000. (After Thoma.)

the vessel, but the fluid portions of the blood also pass through. This, of course, cannot be directly observed under the microscope, but we can easily see that the tissue becomes thicker and infiltrated with fluid. A part of the fluid is retained in the meshes of the tissue, and a part passes directly through to the surface. These vascular changes last for a considerable time, and, if the mesentery of the frog has remained under observation a long while or if it be allowed to become dry, the circulation will finally cease and the part will become gangrenous. If care be exercised in the preparation of the specimen and the mesentery be replaced in the abdominal cavity, the vessels in the course of a few days will return to their normal condition.

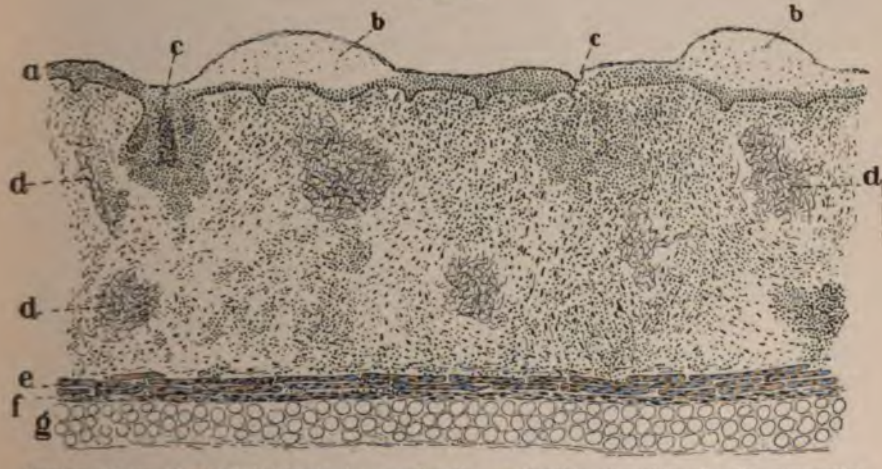
These are the main vascular phenomena which can be observed directly under the microscope. The process in all animals is the same. Thoma has observed the circulation in the mesentery in the small mammalia, under both normal and pathological conditions, and the same phenomena occur. The same process may be observed in the wing of a bat under the microscope, but in this case it will be necessary to produce some mechanical or chemical injury to the tissues, the mere exposure under the microscope not being sufficient.

The inflammatory changes in the circulation may with advantage be studied in the frog's tongue. This contains more vessels than the mesentery and is relatively richer in capillaries. The tongue is attached to the jaw by its anterior extremity, and it can readily be drawn from the mouth, spread out over a cork ring, and the circulation observed. Inflammation may be produced by the application of dilute croton oil (1 drop of croton oil to 40 of olive oil) to the surface, removing it in a few minutes, otherwise it will produce coagulation of the blood in the vessels with entire cessation of the circulation. The same phenomenon which is seen in the mesentery takes place here. There is a period of intense active hyperæmia which gives place to stagnation, with emigration of white and red corpuscles and increased transudation. The tongue becomes swollen from infiltration with fluid and cells. The changes are the more striking the more limited is the injury to the tissue. The croton oil tends to diffuse all over the surface, but a circumscribed inflammation may be produced by touching the surface with a crystal or a pointed stick of nitrate of silver. Various degrees of vascular disturbance may be seen, which is most intense immediately around the eschar which has been produced by the caustic, and which gradually gives place to the normal circulation. The caustic produces, where it comes in contact with the tissue, coagulation of the blood in the vessels, with cessation of the circulation and necrosis of the tissue. The necrotic tissue is converted into a brown slough which is presently cast off. Immediately around the eschar is a dark-red zone. In this the blood-vessels are greatly dilated, the circulation is very slow, in places completely stagnant, and the tissue between the vessels is filled with red corpuscles which have passed through the walls. The redness immediately around the necrotic spot is principally due to hemorrhage by diapedesis. Even with the naked eye it can be distinguished from the redness due to hyperæmia by its greater intensity and diffuseness. Outside of this comes a zone in which the vessels are dilated, the circulation is slow, and numbers of corpuscles, both white and red, but principally white, are

passing through the walls of the vessels and accumulating in the tissue. This zone gradually fades off into one in which there is active arterial hyperæmia. In this way all the changes which gradually develop in the mesentery can be seen taking place at one time. Here, as in the mesentery, it is evident that there is also an increased exudation of the fluid portions of the blood, because the tissues become swollen and œdematous. These areas, which we have referred to as zones, are not sharply marked, but one gradually gives place to the other.

The same process can be studied on non-transparent parts by hardening them at various intervals after the production of the injury and examining the sections. Acute inflammation may be excited in the ear of a rabbit by rubbing it with croton oil. The oil should be diluted with 5 or 6 parts of olive oil, otherwise a total necrosis of the tissue may be produced. Almost immediately the ear becomes actively red. In twenty-four hours it is red and swollen. The redness is not always due to hyperæmia. Here and there small, irregular red splotches may be seen which are due to hemorrhage into the tissue. The swelling involves the entire ear even if the croton oil was only applied to the tip. On the inside of the ear small vesicles filled with clear fluid are frequently found (Fig. 5). Sections of the ear after hardening in various

FIG. 5.



Section of ear of rabbit thirty-six hours after the application of croton oil; the connective tissue is swollen from infiltration with serum, leucocytes, and fibrin: *a*, epidermis; *b*, vesicle-formation; *c*, accumulation of leucocytes around necrotic hair-follicles; *d*, fibrin; *e*, muscular layer; *f*, perichondrium; *g*, cartilage.

solutions—of which Fleming's solution is the best—show the vessels dilated, and in some cases entirely filled with white corpuscles. Frequently the white corpuscles are confined to the inner lining of the veins, and in favorable sections they may be caught in various stages of emigration. In the areas of hemorrhage the congestion is intense, the tissue is filled with red corpuscles, but no rupture of the vessels can be made out. In the tissue everywhere there are immense numbers of cells of the same appearance as those within the vessels. They are usually more numerous close beneath the epidermis, and the tissue may be so

packed with them that nothing more can be seen. They are not only in the tissue beneath the epidermis, but numbers of them have entered into this, lying in the spaces between the cells, and in the fluid in the small vesicles numbers of them are seen. Toward the middle of the ear, where the tissue is looser, the white corpuscles are less numerous, and the meshes of the tissue are forced apart by infiltration with the fluid which has escaped from the vessels along with the leucocytes. In the swollen tissue toward the root of the ear, away from the area of injury, there are few or no leucocytes. Fibrin in various amounts may be contained in the tissue.

If an injury be produced in non-vascular parts, the same changes which are seen in the vessels of the mesentery or in the vessels of the rabbit's ear will take place in the surrounding vessels which provide the nutrition for the non-vascular territory. The cornea has usually been selected for the study of inflammation in non-vascular tissues. If the central portion of the cornea of a rabbit be injured by touching it with a stick of nitrate of silver or caustic potash, a necrosis of the tissues limited to an area not exceeding 1 to 2 mm. in diameter may be produced. The tissue immediately affected by the caustic becomes white and opaque; it afterward becomes dry, and a scab is produced which is thrown off. For a time no change will be perceived in any portion of the cornea, either immediately around the injured tissue or at a distance. If a very thin cornea, as the frog's, be chosen for the experiment, the corneal corpuscles immediately around the injury are more easily seen than elsewhere, and this is doubtless due either to coagulation of the protoplasm of the cell or to changes which have taken place in the intercellular substance. In the area of the eschar there has been total destruction of the cells and of the intercellular substance as well, but around this, where the action of the caustic was less intense, it is probable that necrosis of the cells with coagulation of the protoplasm has been produced without any alteration in the character of the intercellular substance. In the course of a few hours changes begin to appear in the periphery of the cornea close to the sclera. The first change which is appreciable is a slight cloudiness around the entire periphery of the cornea if the injury has been produced exactly in the centre. If the caustic was applied closer to one margin, the cloudiness will begin on the margin nearest the injury. The cloudiness rapidly increases, and extends over the entire cornea up to and around the injured portion. At first the entire tissue between the sclera and the site of the injury is clouded, but the cloudiness gradually becomes more marked around the injury, and the periphery of the cornea after three days may become completely clear. When the cornea is removed, split up into thin lamella, and examined, it is found that the cloudiness is due entirely to the presence of leucocytes in the lymph-spaces of the tissue. If the vessels of the sclera are examined in the beginning of the cloudiness, the same changes are found in them which were seen in the vessels of the frog's mesentery and tongue.

The experimental study of inflammation of the cornea has played a most important part in the development of our knowledge of inflammation. It formed the battle-ground between the adherents of Cohnheim, who believed that the cells in an acutely inflamed tissue were exclusively

derived from emigration of leucocytes from the vessels, and the adherents of Virchow (and later Stricker), who believed that if emigration of leucocytes took place at all, it only played a subordinate rôle, and the new cells were derived from multiplication of the fixed cells of the tissue.

The cornea being a non-vascular organ, it was first thought that the new cells which appeared in it after inflammation was excited must be derived from the fixed cells. Cohnheim showed that the new cells do not first appear around the injury, but in the periphery, and thence gradually make their way to the centre; further, that examination of the vessels of the sclera showed the same changes which had been observed in the frog's mesentery. He showed further, in a most ingenious way, that the cells came from the vessels. It was known that when carmine, cinnabar, or any finely-divided solid substance was injected into the circulation, the white corpuscles of the blood would take up the foreign material. He injected such substances into the abdominal vein of a frog, and found them in the new cells of the inflamed cornea. According to the theory of inflammation developed by Cohnheim, which was accepted without reserve by his pupils, the essential feature of inflammation is an alteration of the walls of the blood-vessels, in consequence of which they become more permeable, and allow not only the fluid parts of the blood to pass through more easily, but the corpuscles as well. The tissue-cells played no part in the process, and not only the pus-corpuscles, but all of the new cells found in the inflammatory area, came from the blood.

Cohnheim was not the first to observe the emigration of the leucocytes. His observations were made in ignorance of the earlier work on the subject, but he saw the importance of the process and investigated farther. Cohnheim's first observations on the cornea were published in 1867. As early as 1842, Gulliver described the cells found in severe inflammation and suppuration, and compared them to the white corpuscles. He seems also to have been the first to observe an increase in the number of white corpuscles in the blood during the process of inflammation. Addison in 1845 called attention to the similarity of the blood-, lymph-, and pus-corpuscles. He found that all these cells had amœboid movements, that they resembled one another greatly, and thought it possible that they might be the same cells. Quitzman, who reviewed the article of Addison in *Canstatt's Jahresbericht*, says that it shows great penetration and admirable observation, but that the only proof of the identity of the pus-cells and the leucocytes would be the observation of the actual passage of the leucocytes through the walls of the vessels. Various other observers after this called attention to the similarity in the appearance of white corpuscles and pus-cells, and in some of the atlases of pathological anatomy pus-cells and white blood-corpuscles are shown side by side. Virchow in numerous publications mentions this similarity. The actual proof of the matter was given by Waller in England in 1849, but his observations attracted little attention and were soon forgotten. Then the matter rested until Recklinghausen in 1862 showed that the normal connective tissue contained cells, similar to the leucocytes, which wandered through the tissue in the lymph-spaces. Although we know now that the leucocytes form the great mass of the

cells in the exudation in an acute inflammation, they are not the only ones present, and the essential feature of inflammation is not the lesion of the vessels.

For the excitation of inflammation an injury of the tissue of some sort must be produced, and the mode by which the injury is produced is of little importance. The injury may be from a trauma, and a lesion of continuity may be produced. In many cases it is difficult to show the anatomical lesion which the injury has produced. Pressure or traction exerted on a tissue may act as a trauma, and the extent of the injury will depend upon the elasticity of the part. The consequence of pressure may be the severance of the connection between certain parts, or, when the pressure is of longer duration, the nutrition of the part may be affected and necrosis take place. Very slight mechanical injury in individuals with very vulnerable tissues may produce evident inflammation. In the case of the mesentery we have seen that even the laying bare of a part which is ordinarily covered may develop inflammation. Zahn has shown that when the mesentery is fully protected from drying and other injuries, and preserved from contact with the bacteria in the air, it may remain exposed for hours without inflammation taking place. The chemical injuries are probably more extensive than the traumatic. They may directly produce a necrosis of the tissue, with coagulation of the cells and intercellular fluid, or they may exert an injurious action on certain special cells. The injurious action of bacteria is probably for the most part chemical, the tissue being affected by the substances which they produce. The action of some of the bacteria on the tissues is not inflammatory: they may exert a specific action on the cells, causing them to proliferate and to produce definite new-formations of tissue. Even this action may be accompanied by inflammation, for all such newly-formed tissues are prone to degeneration, and the tissue reacts to the injury of these abnormal products just as it does to injury of its normal constituents. Heat and cold may excite inflammation if they are of sufficient intensity or their action is sufficiently prolonged to have an injurious influence. In the same way, if injury be produced by interference with the normal blood-supply of any part, inflammation is excited around the injured tissue. Electrical stimulation cannot excite inflammation unless it be of such a nature that the tissue is directly injured. Foreign bodies only act as exciters of inflammations by the injury which they produce in the tissue around them. Even in the inflammations of internal organs which are far removed from the dangers of traumatism the same thing is true. The injury to the tissue which is the cause of inflammation may be due to the presence in the tissues of chemical substances which are formed elsewhere in the body, and which exert an injurious action on certain of its cells. The inflammation of the kidney produced by chrome salts and cantharidin are examples of this.

Certain phenomena which are easily appreciable have since the time of Celsus been regarded as indicating inflammation. They are in some cases more evident than in others, and certain of them may be absent or predominate over the rest. They appear in their most typical form in acute inflammations of the skin. If we take for example the furuncle or the infectious inflammation which develops in the skin around the

hair-follicle or glands, we find at the height of the process that the inflamed area is redder than the surrounding skin. It is warmer to the touch, and if the temperature be taken with a surface thermometer, it may be several degrees warmer than the neighboring skin. It is swollen, appears as an elevation, and is painful.

The redness is due to the greater amount of blood which is contained either in the vessels or, in the form of hemorrhage, in the tissues of the part. The character of the redness varies. In the early stages of the inflammation and at the periphery it is a bright red, almost approaching the color of arterial blood. As the inflammation advances, and in the centre of the furuncle, it changes to the dark color of venous blood. When the blood is contained in the vessels alone, the redness may be made to disappear by pressure, the blood in the dilated vessels being driven out of them. The redness is also due to hemorrhage in the tissue. The areas of hemorrhage generally appear as circumscribed spots, distinguished from the hyperæmia by the more intense color. They are easily seen in the inflamed ear of the rabbit, and are most marked where the action of the injurious agent has been most intense. By varying the dilution of the croton oil which is applied to the ear the amount of the hemorrhage in the tissue varies, and is always greatest when the less diluted oil is used. There is no tissue in the body so well adapted to show inflammatory hyperæmia and hemorrhage as the acutely inflamed pleura. When this is stripped off and held to the light, it is of a bright-red color, a beautiful network of dilated vessels can be seen, and between these the tissue has a general diffuse redness due to injection of the capillaries. Here and there in the tissue can be seen red splotches varying in size from 1 to 10 mm. in diameter, which are due to hemorrhage. More blood is brought to the inflamed part by the dilated arteries, and more flows from it. This increased passage of blood through the inflamed area takes place in spite of the slowness of the circulation in the dilated veins. In the early stages of inflammation, in which there is dilatation with increased rapidity of the circulation, it is evident that this must be the case, and in the later stages, in which there may be almost complete stagnation in the central portion of the area, in the periphery there is an active circulation in dilated vessels. Lawrence long ago showed that there was a greater flow of blood from an inflamed part by opening corresponding veins coming from an inflamed and from a normal part.

There have been various theories advanced to account for the inflammatory hyperæmia. After Bernard showed the effect of cutting the sympathetic on the circulation of the rabbit's ear, the idea arose that the inflammatory hyperæmia might be due to paralysis of the vasomotor nerves. It can be shown that this is not the case. After section of the sympathetic the hyperæmia develops at once; in inflammation it comes on slowly and extends slowly. Further, the hyperæmia produced by section of the sympathetic never reaches the intensity of the inflammatory hyperæmia. If the ear is inflamed after section of the sympathetic, an intense hyperæmia develops—more intense, as a rule, than the inflammatory hyperæmia of the ear with a normal nervous supply. Then the opposite idea was held, that the effect of the injury was to produce a spasmodic contraction of the arteries, so that there

was really a diminished supply of arterial blood to the part; the hyperæmia then was supposed to be due to the entry of blood into the inflamed part from surrounding parts by the collateral circulation. There is usually in inflammation a temporary contraction of the arteries, but this may be entirely absent, and it quickly gives place to dilatation. The theory of stasis has also been used to account for the hyperæmia. This theory was intimately connected with the humoral pathology and was advocated by Boerhaave. It was supposed that in inflammation the character of the blood was altered, the corpuscles becoming more adhesive, and in consequence flowed through the vessels with more difficulty and accumulated in the inflamed part. These views with regard to the hyperæmia of inflammation have been given up, and the two theories at present used to explain it are that of Cohnheim and that of Virchow. Cohnheim explains all the vascular phenomena of inflammation by an alteration of the walls of the blood-vessels produced by the action on them of the agent causing the inflammation. Virchow explains the congestion by an alteration in the attraction between the blood and the tissues. Cohnheim supposed that the changes in the vessels were passive in character, and were due to the effect of the injury on them, and he attempted to prove this in various ways. He showed that when the blood was cut off from the vessels for varying periods, and then again turned into them, all the phenomena of inflammation could be produced, the degree depending on the length of the anæmic period. By cutting off the blood from them he supposed the nutrition of their walls was affected, and thus an injury limited to the blood-vessels was produced. He does not attempt to define the character of the alterations which the vessels undergo, and supposed that there might be either chemical or physical changes produced in them which were so delicate that they could not be detected by our methods of investigation, and which manifested themselves only by their effects. Almost all that we know about pathological alterations in blood-vessels relates to the various degenerations of their walls. It is certain that there can be no alteration of the walls of the blood-vessels without affecting the tissues at the same time. The effects of the anæmia produced by shutting off the circulation from the ear will be felt by the tissues as well as by the walls of the vessels, and the inflammation which follows will be due to the injury produced in the tissue. There is much which is opposed to the theory of Cohnheim. The dilatation of the vessels extends far beyond the area immediately acted on by the trauma. Samuel has shown that if the upper portion of a rabbit's ear be inflamed by exposing it for a few minutes to water of the temperature of 54° C., an intense congestion is produced which affects not only the vessels in the part which has been directly acted on by the heat, but extends to the main artery of the ear. The central artery is dilated in its entire course and pulsates strongly. When the artery is cut a considerable distance below the inflamed area, more blood flows from it than from the artery of the normal ear at the same point. In the case of the cornea it is difficult to assume that the action of the injury producing the inflammation could have extended to the vessels of the sclera. It may probably be assumed for a chemical injury, but in the case where an inflammation is excited by passing a thread through the centre of the

cornea it is impossible to suppose that the mechanical trauma could have affected vessels so remote. If one hand be acutely inflamed, the arteries on the inflamed side are dilated and pulsate more strongly than on the normal side. In vascular tissues the inflammatory phenomena, the dilatation, the emigration, etc., do not take place so far away from the injured tissue as the sclera is from the centre of the cornea. Only those vessels which are immediately concerned in the nutrition of the tissue will be affected. All the more recent work on the circulation has removed the blood-vessels more and more from a passive rôle in nutrition. The increased transudation is not due to the vessels becoming simply more permeable, but is due to active changes in the vessels brought about by influences acting upon them. The view of Virchow that the hyperæmia is the result of an alteration in the attraction between the blood and the tissues is probably more nearly correct than that of Cohnheim.

The blood-supply of an organ is regulated entirely by the need of the organ. An increase of function is accompanied by hyperæmia. The hyperæmia is not the cause of the increased function, but it is demanded by the greater needs of a tissue for blood when its functional activity is increased. In the case of a gland more blood must be brought to the part, not only to nourish the cells in their increased activity, but to supply a greater amount of material from which the specific substances secreted can be drawn. We know from the work of Heidenhain that in the ordinary process of secretion the capillaries do not play a passive part, allowing indefinitely all the fluids of the blood to pass through, from which the cells may take up certain specific elements, but the capillaries themselves may be regarded as true secreting structures, and they allow only the substances necessary for each particular tissue to pass through them. When a portion of an organ undergoes atrophy or when there is a permanent loss of substance, however brought about, not only will the supply of blood be diminished by a reduction of the calibre of the blood-vessels brought about by contraction of the muscles, but it will be permanently lessened by the formation of a tissue inside of the artery which brings about a permanent diminution of its calibre. On the other hand, when a tissue calls for a greater amount of blood than can be supplied by the artery, as in the case of collateral circulation when one of a series of small arteries takes the place of a larger, the calibre of the artery will not only be increased by a relaxation of its walls, but it will be permanently increased; it will, in fact, become larger by growth.

The hyperæmia in inflammation is apparently called forth by the needs of the tissue for repairing, and for in other ways setting aside the consequences of the injury.

The temperature of the inflamed part is increased. It is due solely to the fact that more heat is brought to the part by the increased afflux of arterial blood, and the rapidity of the circulation does not allow sufficient time for its dissipation. When active hyperæmia is produced in the rabbit's ear by section of the sympathetic, it can easily be shown by folding the ear over an ordinary thermometer that the temperature of the inflamed ear is four or five degrees above that of the normal. The first exact experiments with regard to the temperature in inflamed parts were made by John Hunter. Hunter showed that the fluid con-

tained in a hydrocele had a temperature when it was tapped of 33.3° C., and on the next day, after actual inflammation had taken place, the introduction of a thermometer into the sac showed a temperature of 37.8°. He showed further that when an acute inflammation was produced in internal parts, as in the pleura, the peritoneum, the pericardium, or the deep muscles in the back and legs, the temperature of the inflamed part not only did not exceed, but it frequently did not reach, the normal temperature at the same place. As a result of his experiments Hunter taught that in local inflammation the temperature does not exceed that of the interior of the body. The correctness of Hunter's conclusion was opposed later by Simon and Weber, who found in peripheral inflammations produced by fracture of bones or by the injection of croton oil into an extremity that the temperature of the inflamed part was greater than that of the blood in the artery going to the part. This was in accord with the theory of Zimmerman which afterward appeared. It is known that a general systemic affection in which the temperature of the entire body is increased frequently accompanies a local inflammation. This is the inflammatory or traumatic fever. Zimmerman advanced the theory that the inflamed part represented a local production of heat which led to increased temperature in the entire body, the increased temperature of the body being due to the heating of the blood in the inflamed part. A repetition of all of these experiments with more exact methods of measuring the temperature by the use of the thermopyle and the galvanometer, which were carried out by Jacobson and his scholars, showed that the temperature of the rabbit's ear in the course of inflammation produced by croton oil is higher than that of the normal ear, but considerably lower than that of the rectum or vagina of the animal; and further, that in inflammation of the deep muscles of the leg there is very slight or even no increase of temperature over that of the sound leg. In acute pleurisy and peritonitis the temperature of the inflamed cavity is the same as, or sometimes less than, that of the blood inside of the heart. The degree of heat in the inflamed part will differ materially according to the character of the inflammation. In the early stages of inflammation, when there is an active arterial hyperæmia, the temperature will be greater than in the later stages, when the active hyperæmia has given place to stagnation. Also, in an intense inflammation produced in the rabbit's ear, in which there is stagnation and a great deal of hemorrhage in the tissue, the temperature, instead of being greater, may be considerably less than that of the opposite ear. In any experiments with regard to temperature in inflammation the temperature of the inflamed part must always be compared with the temperature of the interior of the body of the same animal. A considerable amount of fever may be produced by even a comparatively slight degree of inflammation, and if the temperature of the inflamed part were simply compared with that of the usual normal temperature of the animal, erroneous conclusions might be drawn.

Pain in inflammation is due to the distention of the part and the pressure which is produced on the nerves, or by the direct action of the inflammatory cause on the nerves. The character of the pain will differ in different tissues of the body and in the various sorts of inflammation. In very acute inflammations, when the swelling has taken place rapidly,

the pain frequently has a marked pulsating character, because every addition of blood which is brought to the part by the systole of the heart will temporarily increase the pressure on the nerves, and consequently the pain. It is evident that the pain in tissues poorly supplied with nerves will be less severe than in parts which are extremely sensitive. The anatomical character of a tissue will also have an influence on the degree and character of the pain, which may be entirely disproportionate to the abundance of nerves. In inflammation of dense fibrous tissues, which are incapable of much distention, greater pressure and injury of nerves are brought about than in a part where the tissues are more lax. Inflammations of the periosteum or of the fibrous tissues about joints are intensely painful. Not only do these local conditions influence the degree and the character of the pain, but general conditions of the body may also exert an influence. A condition of hyperæsthesia may be brought about either by local changes in the nerves of the inflamed part or by the effect of fever on the nervous centres.

The swelling of the inflamed part is due to an increase of material in the part. There is not only an increased amount of fluid in the inflamed part, but the cellular elements are also increased. The volume of a part in the state of inflammation is also slightly increased by the increased amount of blood in the vessels, but this has so slight an influence that it may be left out of consideration. We know that hyperæmia will produce an increase of volume. The fluid which is present in the inflammatory tumor comes from the blood-vessels; the transudation is increased. Not only does the fluid accumulate in the tissues in this way, but there is an increased flow in the lymphatics going from the part. Cohnheim showed that when a canula is placed in a main lymphatic of the leg after an acute inflammation has been produced in the foot by the action of croton oil or hot water, there is a greatly increased flow of lymph as compared with the other side. On dissecting out the lymphatics coming from an inflamed part they are found full and turgid. Chemical analysis of the lymph in inflammation has shown that it is much more concentrated than the normal lymph. A solid residue of 6 or 7 per cent. has frequently been found in the inflammatory exudation in man, and Lasser has shown that the lymph from the inflamed foot contains $6\frac{1}{2}$ to 8 per cent. of solid constituents. The salts are not increased. All investigators are agreed that they are found in almost the same proportions in the inflammatory transudations as in the normal lymph. The increased concentration depends entirely upon an increase in the amount of albumin. There is a marked difference between the character of the œdematous fluid in inflammation as compared with that of the ordinary dropsy from chronic passive congestion. The dropsical accumulations contain but little albumin, and the normal lymph has an intermediate relation between the two in the proportion of albumin. In inflammatory lymph there is a greater tendency to coagulation than in normal lymph. Dropsical accumulations either do not coagulate at all or very slowly, and a soft clot is produced. Lasser found difficulty in obtaining lymph from the lymphatics of an inflamed part on account of its great tendency to coagulation, the canula becoming in a short time filled with the clot. The increased coagulability of the lymph is due in great part to the increased number of colorless corpuscles.

Cohnheim regards this alteration in the character of the transudation as due entirely to alterations in the walls of the blood-vessels. The character of the filtrate is altered, because the character of the filter, the wall of the blood-vessel, is altered. He rightly supposed that the increased transudation in inflammation is not due to a simple increase of pressure within the vessels, because the character of the fluid is different from that in chronic passive congestion, which is due to such increase. It is impossible to compare exactly the character of the transudation in the two cases by observation of the fluid in the lymphatic vessels. In chronic passive congestion the lymph as it escapes from the vessels comes in contact with a tissue which is unaltered. In inflammation the lymph comes in contact with abnormal tissues. In the tissue of the part in which there is inflammation there are various changes taking place, various degenerations have been produced by the injury which has caused the inflammation, and all of these factors may exert an influence on the character of lymph flowing through it. It is probably true that in inflammation the character of the transudation passing through the vessel-walls is different from the normal, and different from that in chronic passive congestion. But its character is not due to changes which have taken place in the walls of the blood-vessels, in consequence of which they passively allow a different fluid to pass through them, but the vessels actively secrete a different fluid. The character of the transudation may differ also in the various sorts of inflammation. A different fluid is needed by the tissues, and there will be a difference in the transudation, just as there is a different lymph secreted by the blood-vessels of the kidney as compared with that secreted by the blood-vessels of the pancreas. This increased flow of lymph in inflammation has a purposeful character independent of affording a greater degree of nutriment to the tissues. By it soluble chemical substances—substances either producing the inflammation of the tissue in the first place or substances which are produced in the inflamed area by the action of bacteria which may be there—are diluted or washed away.

In the inflamed part the lymph will accumulate in the interstices of the tissue, in the lymphatic vessels and lymph-spaces, and give rise to œdema of the part. By pressure it may be pushed from one place into another, just as by pressure the blood can be removed from the vessels of a part. A deep depression or pit remains at the seat of pressure, which will disappear when the fluid returns. There may be inflammations in which the swelling is due entirely or almost entirely to the increased fluid transudations. Such inflammations may be spoken of as œdematous inflammations, and they generally represent a milder degree of inflammation. One of the most marked examples of a simple œdematous inflammation is that produced by the action of the sun. We may have here a very mild degree of inflammation in which there is only hyperæmia with increased fluid transudation.

Samuel, in his work on inflammation, has very properly separated the œdema in an inflamed part due to the inflammatory cause from the œdema in adjacent parts which frequently supervenes on inflammation. Thus, when the extremity of a rabbit's ear is inflamed there will be œdema not only in the inflamed portion of the ear, but also lower down in the ear, where no injury of the tissue has been produced. This

Samuel distinguishes as inflammatory œdema in contradistinction to the œdematous inflammation. It is due merely to an extension of the œdema from the inflamed territory, and is sometimes spoken of as collateral œdema. The same thing can be seen in the subcutaneous œdema of the chest-walls which sometimes accompanies inflammation of the pleura. This œdema was also studied fully by John Hunter, who speaks of it as being squeezed from the inflamed part into adjacent parts.

The tumor contains, in addition to the fluid, a certain portion of solid material. In the first place, it contains a variable amount of fibrin. Not only is the lymph which passes from the inflamed part richer in fibrin than the normal lymph, but in many inflammations there is formation of fibrin, a certain amount of coagulation, in the inflamed part itself. In the inflammatory exudation all the necessary elements for the formation of fibrin are present. Fibrin is due to the action of a ferment, usually spoken of as the fibrin-ferment, on certain substances in the blood. This fibrin-ferment, there is every reason to believe, is formed from the disintegration of cells. In the ordinary process of coagulation it is probable that the leucocytes of the blood form the source of the ferment, but it may be produced by the disintegration of the cells of the tissue. In the inflamed part there is an abundance of fibrinogen in the exudation, and the fibrin-ferment is produced by the disintegration of cells. Fibrin is present in almost any acute inflammation. On examination of the inflamed ear of the rabbit after suitable hardening a varying amount of fibrin is found in the exudation, the amount depending largely on the intensity of the inflammation. In some cases there are only a few fibrillæ scattered through the tissue, and in other cases there are large masses of it. In many cases the fibrin may be seen radiating out from the necrotic cells. The hardness of the inflamed part, especially the so-called brawny induration which is found in certain sorts of inflammation, is due to the presence of fibrin. In certain forms of inflammation the fibrin may be present in excessive amounts.

In any inflamed part in which there is an increased number of cells in the tissues a certain number of red corpuscles will nearly always be found. With regard to these we know that they could only come from the blood-vessels, and they are found in varying numbers, dependent on the character and intensity of the inflammation. In some cases they are present in such excessive numbers that the inflammation is spoken of as hemorrhagic. These corpuscles escape into the tissues from the capillary vessels, and can easily be seen to pass through the walls of these vessels when the inflammation is directly observed under the microscope.

A large proportion of the cells—and in some inflammations nearly all—are white corpuscles which have emigrated from the vessels. With the increased knowledge of the corpuscles of the blood which has come from its more careful study in recent years we know that the white corpuscles differ materially from one another in form, and that they have different values and different origins. The most numerous corpuscles are the so-called polynuclear leucocytes. These form between 80 and 85 per cent. of the entire number of leucocytes, and are characterized by an irregular nucleus. This nucleus stains brightly, and, although spoken of as a multiple nucleus, it is in most cases a single

nucleus divided into several masses which are connected together by fine filaments. These corpuscles also differ from one another in the chemical composition of their protoplasm. This is shown by their reaction to staining agents. In the great majority of them the protoplasm contains very fine granules which are stained with the neutral or basic aniline colors. In a certain proportion of them the granules in the protoplasm are larger and stain brightly with eosin. Next to these in number and importance are the so-called leucocytes of the blood. In these two sorts can be distinguished. The most numerous are corpuscles which are about the size of the cells contained in the lymph-glands, and which have a large round nucleus, and a very small amount of protoplasm around this. There are a certain number of larger cells of the same character. Although other cells have been described in the blood, these are the only ones which need concern us in the study of inflammation. In the corpuscles first described the nucleus frequently takes the shape of a horseshoe.

The polynuclear leucocytes are the most numerous of the cells found in the swollen tissue in acute inflammation. In some cases they are apparently the only new cells found in the tissue. In the inflamed cornea in the early stages of inflammation the cells found in the lymph-spaces are exclusively these. There have been many theories advanced to explain how these cells pass through the walls of the vessels. The first idea held by Cohnheim was that the passage was effected by means of their amœboid movements—that they crawled through the walls. The corpuscles when adhering to the walls before the emigration has begun show active amœboid movements, and when in the act of passing through, both the part outside of the vessels and that inside show active amœboid motion. Cohnheim afterward gave up this idea, and considered that the white corpuscles, like the red, did not pass through by means of their own activity, but by passive filtration. He was chiefly led to this view from the fact that when the blood-current ceased in the dilated veins the process of emigration ceased. There may be another explanation of this. The leucocytes are probably kept against the wall of the vessel by means of the blood-current, and probably by the continuance of the circulation they are excited to more active amœboid movements. Their collection in the vessels of the inflamed part is partly due to the slowness of the circulation, but more to a voluntary action on their part. The inflamed tissue exerts an attraction for them. Substances which have the power of stopping the amœboid movements of the corpuscles also stop the emigration. Thoma has shown that when salt solution of the strength of 1 : 12 is injected into the blood the amœboid movements of the leucocytes cease, and the process of emigration ceases in inflammation. If the frog is completely chloroformed, the action of the chloroform may extend to the leucocytes and stop any amœboid movements, and emigration will not take place.. Cohnheim supposed that the filtration of the corpuscles through the vessels was due to an alteration in the vessel's wall, together with the increased pressure. He did not attempt to define the character of this alteration but supposed it might be physical or chemical. The most accurate observations on this subject seem to show that the leucocytes pass between the endothelial cells of the vessels. There are small openings

between these cells in the normal condition of the vessel, and these openings probably become larger when the vessel is dilated. Bouchard thinks that the endothelial cells in the vessels may contract and assume a round form, leaving large openings between them through which the corpuscles pass. The emigration of the leucocytes is due to active amœboid movements on their part, possibly assisted by a more porous condition of the walls of the vessel.

It is known that chemical substances have the power of attracting or repelling cells capable of independent motion. This was shown first by Engelman in certain of the myxomycetes. It is seen in a marked degree in bacteria. The phenomenon was carefully observed in the leucocytes by Gabrischweisky. He found that when capillary tubes were partly filled with certain substances and placed in the tissues of animals, the tubes became filled up with leucocytes. When they were filled with indifferent substances, only a small number of leucocytes entered into them, and other substances exerted a repellant action. Necrotic tissue of all sorts attracts the leucocytes to it. No better proof can be given of this than the collection of leucocytes around a lesion in the centre of the cornea. Although they pass from the vessels of the sclera, they do not wander into the tissue at random, but march directly to the inflamed focus. What the nature of the chemical substance is which exerts this attraction for the leucocytes we do not know. It is produced in necrotic tissue everywhere. Although most of the bacteria have a decided action in attracting leucocytes, this attraction is more strongly exerted when they are dead than when they are living. It is probable that substances are produced in the necrotic tissues which by diffusion extend their action to the vessels, producing in these the inflammatory phenomena. Not only is the influence felt on the vessels, but it extends to the cells within them, causing these to pass through the walls and to accumulate around the necrotic tissue.

The cells in some inflammations, and in the early stages of all, are composed entirely of these polynuclear leucocytes. Along with them in other cases cells similar to the lymphocytes in the blood appear. Usually they appear somewhat later than the polynuclear leucocytes, and in inflammations of a less active character. They are principally formed in the outermost zone of the inflammatory area, and usually are seen in small groups around the vessels. There is much dispute about their origin. While all observers are agreed that the polynuclear leucocytes come from the blood, it is held by some that the small lymphocytes have the same origin. Others hold that they are formed by proliferation of the tissue-cells. Baumgarten especially holds the former view. His studies of the cells in inflammation were made on the histogenesis of tubercle. The round lymphocytes enter largely into the structure of this, and he believed that they come from the blood and enter into the tubercle, which is at first formed of large cells derived from the tissue. Ribbert and Marchand also believe that these cells are leucocytes. In the more chronic inflammations the new cells may be almost exclusively of this character. There are many objections to these views. Although we are not able to study the course of inflammation so thoroughly in man and the mammalia as in the frog, still by the modern methods of histological technique we are able to study the process which is going on

in any one stage of inflammation. As far as I have been able to observe the process of acute inflammation in man by means of thin sections of tissue carefully hardened, the polynuclear leucocytes are the only ones which pass through the vessels. In acute inflammation of the skin the vessels of the papillæ are closely packed with these cells, and they may be observed in every stage of passage.

The origin of the cells in the inflamed territory has been a subject of dispute in pathology. Cohnhein at first believed that all the new cells were leucocytes, but he afterward modified his views, and admitted that in the later stages of inflammation regenerative phenomena took place in the surrounding tissue-cells, leading to the formation of new cells. The new cells so formed were distinguished from the inflammatory cells, and were destined to renew the tissue which had been destroyed. Cohnheim's view was directly opposed to that of Virchow. According to Virchow, the essential condition in inflammation is an altered nutrition of the tissue. In consequence of the injury—or, as he calls it, the irritant—the cells of the tissue were variously affected. They were roused to an increased activity which might be simply nutritive or formative. They might increase in size, with an increase of their functional activity, or they might multiply. All of the vascular phenomena he considered to be secondary to this altered nutrition of the tissues, and due to this. Virchow was one of the earliest authors to recognize the similarity of the new cells in inflammation to leucocytes, but he supposed, in spite of the similarity, that they were formed by multiplication of the cells of the tissue. Virchow's views underwent some modification at the hands of Stricker. While Stricker does not deny the emigration of the leucocytes, he thinks that these form but a small part of the cells which are formed in the inflammatory exudation. He accepts the view of Virchow that most of the cells are derived from proliferation of the cells of the tissue, and he compares the cell under its ordinary conditions to a bent bow. He holds that they have a certain amount of stored-up formative energy, which under the influence of the inflammatory irritant can be expended in a new formation of cells, the inflammatory irritant acting as the unloosing of the arrow. Afterward he still further modified this view, holding that not only do the cells of the tissue proliferate, but new cells are formed from the intercellular tissue. This view, first given by Stricker, that a new formation of cells can take place from the intercellular substance, has been taken up by Grawitz. According to Grawitz, in the development of the tissue only a certain number of cells are used up in the formation of intercellular substance. Many of them, without losing their character as cells, become invisible and apparently form a part of the intercellular substance. Under the influence of the inflammatory stimulant these cells, which Grawitz speaks of as the slumbering cells, become visible, multiply and form a large part of the cells in the inflammatory tumor. Cohnheim was led to alter his former views as to the exclusive presence of leucocytes in the inflammatory tumor by the work done in his laboratory by Senftleben. Various observers had described changes in the corneal corpuscles during inflammation. Virchow had described swelling and multiplication of cells in the periphery, and considered that the cloudiness of the tissue was due to such changes in the cells. Multipli-

cation of the cells was described by His and numerous other authors, and Axel Key described changes in the cells immediately around the inflamed area. Most of these changes described in the cells were either falsely interpreted as cell-multiplication or they were degenerative phenomena. Senftleben was the first accurately to describe the changes which take place in the corneal cells in inflammation, and to separate the newly-formed cells from the leucocytes. He showed that when the centre of the cornea was cauterized the corneal corpuscles immediately around the eschar were killed by the action of the caustic. The injury to the tissue extended farther than the formation of the eschar seemed to indicate. The necrotic corpuscles contracted, their processes were drawn in, and they became converted into formless masses. The corpuscles immediately outside of this area underwent other changes. They became larger and stained more brightly, the nuclei increased in number, and long processes were given off from them which extended up into the region of necrosis. Nuclei passed from the cells into these long processes, and in this way new cells were formed which took the place of necrotic cells, and represented not an inflammation, but a regeneration of the tissue.

These changes in the cells only take place in the corpuscles adjacent to the necrosis, and no changes are seen in the cells in the periphery where the pus-cells are entering into the tissue. It has been shown that it is possible to produce such slight injuries to the tissue that there is little or no infiltration with leucocytes, and the changes may be limited to regeneration of the cells. In almost any sort of inflammation in any tissue the two processes of emigration of leucocytes and new formation of cells take place. The cellular proliferation takes place later than the emigration. It can be recognized by the various changes which take place in the nuclei preceding cell-division, and in general does not begin until two to four days after the receipt of the injury. The character and the arrangement of the cells can be easily seen in the small foci of inflammation which form around small masses of bacteria which have been carried as emboli into the tissue. These can be produced at will by the injection of pure cultures of the staphylococcus aureus into the ear-veins of rabbits, and their development observed by killing the animals at successive periods after the injection. Such foci will serve as general types of acute inflammation. The micrococci are found in a small vessel, either a capillary or a small vein, which they entirely occlude. They are probably not lodged here as an embolus filling up at once the entire vessel, but one or more lodge in the endothelium and the vessel becomes filled by their growth. In the older foci their growth extends beyond the vessel, and clumps of them may be found in the tissue. Around the group of bacteria there is a distinct necrosis of the tissue. In the necrotic mass the cells may sometimes be recognized, but more generally the whole is converted into a granular mass. In the periphery of the necrosis the tissue is infiltrated with polynuclear leucocytes. These form a wall around and extend into the necrotic tissue. It is probable that the necrotic tissue is formed, to some extent at least, by the leucocytes which have wandered into it so far that they have fallen victims to the same cause which produced the necrosis of the tissue. Although the wall of cells formed around the necrosis is, on

the inside, composed entirely of leucocytes, on the outside these gradually give place to mononuclear cells similar to the indifferent cells of granulation tissue and to the lymphoid cells of the blood. The more advanced the inflammation, the more numerous are they in the tissue. If the animal be killed twenty-four hours after injection of the bacteria, when the small inflammatory foci are not visible to the eye, the cells may be absent. Where they are formed in the tissues is a question. From their close relation to the blood-vessels, and from the fact that in the cells forming the vessels the earliest and most active cell-proliferation is seen, it seems probable that they are formed from these cells. In some of the inflammations produced by bacteria they may be so numerous as to constitute by far the majority of the new cells. Other cells make their appearance in the late stages of inflammation, but they are so obviously connected with repair and new formation of tissue that they will be considered under that head.

There is a purpose fulfilled by the presence of the leucocytes in the inflamed tissue. Whenever there is any dead material in the body, this becomes filled with leucocytes. In such material chemical substances are formed which exert an attracting force on the leucocytes. In the small foci of inflammation formed around masses of staphylococci they are attracted not only by the necrotic tissue produced by the bacteria, but by the bacteria themselves. Capillary tubes partly filled with staphylococci and placed in the tissues speedily become filled with leucocytes. They appear to pave the way for a new formation of tissue. It is by means of the leucocytes that the detritus of dead tissue is removed. In the acute inflammation produced by bacteria they form a wall around these, close up the lymphatics, and prevent to a large extent the further action of the organisms. Metschnikoff has shown that they have the power of taking up and destroying bacteria, and their presence is in this way a source of protection to the organism. This power of eating and destroying material is termed "phagocytosis." Another purpose which they serve is that of furnishing food to the large epithelioid cells which are concerned in the formation of tissue. There can be little doubt that an important purpose may also be served by the fluid exudation in washing out soluble injurious substances from the tissues and in diluting them. Most foreign bodies, especially those of an organic character, when introduced into the tissues, will produce to a limited extent inflammatory changes in the circulation in the vessels around them, with emigration of leucocytes which enter into the foreign body. Pieces of sponge or pith placed in the abdominal cavity become filled with leucocytes. Other substances have little or no effect in attracting them. Finely-powdered glass introduced into the tissue causes a new formation of tissue, an infiltration with round lymphoid or granulation cells, and finally a capsule formation; and this may take place without the emigration of a single leucocyte.

Little is known as to the manner in which the red corpuscles pass through the walls of the vessels, and the conditions favoring this. As a general rule, the more severe the injury produced in the tissue, the greater is the number which pass through. They cannot, like the white corpuscles, pass through by their own active movements, and, as far as can be seen under the microscope, they pass through actually intact

vessels. It may be that from the dilatation of the vessels the stomata become so large that they are forced through by the increased pressure, or small fissures not visible under the microscope may take place by means of which they make their escape. When in the tissues they appear to take no active part in the changes which are going on. In part they find their way into the lymph-spaces and lymph-vessels, and are removed by the lymph-stream. In part they are taken up by other cells, and may contribute to the nutrition of these. In part they remain in the tissue and are destroyed, their pigment being taken up by the cells.

The general character of the swelling differs greatly, depending on the anatomical structure of the part of the body which is inflamed. The so-called parenchymatous organs—as, for instance, muscle, kidney, parotid and other glands—swell in toto when they are inflamed. The swelling is proportional to the degree of the exudation. It will be more considerable in organs which are surrounded by a capsule or membrane which is capable of distention than in those which are surrounded by a membrane incapable of distention. In parenchymatous organs the exudation is in the meshes of the interstitial connective tissue, because this tissue carries the blood-vessels and is more easily distended by fluid. In the inflammation of connective tissue the exudation accumulates in its meshes; it infiltrates it. In a furuncle the exudation accumulates in the loose spaces of the subcutaneous tissue, and in meningitis it accumulates in the spaces of the pia-arachnoid. The same is seen in the substance of the cornea when it is inflamed, but on account of the slight distensibility of this tissue the thickening in the beginning of the inflammation is not a very marked one, and the infiltration appears more as a cloudiness of the tissue due to an interference with its optical properties than as a swelling. In cartilage, in which there are no distensible meshes or canals, the exudation-fluid or corpuscles cannot enter into the tissue; therefore in inflammation of the cartilage of joints the exudation is found in the cavity of the joint, except in the immediate periphery, where under certain circumstances a few corpuscles apparently eat their way directly into the tissue. When the wall of a large cavity is inflamed the inflammatory exudation accumulates in the cavity. That is the case in the serous membranes, also in the dura mater. In the inflammation of periosteum the exudation cannot accumulate in the dense tissues, but it presses in beneath the periosteum, elevating it from the bone. The inflammatory exudation always accumulates where it finds the least resistance; thus in pneumonia it enters the alveoli of the lungs and fills up these, because it finds no place in the alveolar septa. In the same way, it is easily understood that in places where a dense covering prevents the exudation reaching the free surface this covering will be elevated in the form of a bladder or vesicle. This is seen in the example we have given in the inflammation of the periosteum, but a better example is given in the inflammation of the skin. In all forms of acute inflammation of the skin one of the most common of all phenomena is to find the epidermis over the inflamed area elevated in the form of a vesicle. In organs which freely communicate with the outside, and an open way is given for the exudation, it is simply poured out on the surface and escapes. This is the case with all mucous mem-

branes, because their epithelial covering is loose and does not hold the exudation within it as does the epidermis. In consequence of this a formation of vesicles does not take place, but the exudation passes freely through to the surface. This is also the case in the kidneys, where the exudation in part passes off in the urine and appears in the form of albumin.

Inflammation has been divided into two varieties, depending upon the special involvement of certain elements of an organ. In a glandular organ we can recognize the secreting cells and the connective-tissue framework supporting the cells and carrying the blood-vessels. According as the special seat of the inflammation was supposed to involve the specific glandular cells, the parenchyma, or the interstitial tissue, the division has been made of parenchymatous and interstitial inflammation. This division is a false one. If we regard inflammation as the sum of the processes which take place in the tissues on receipt of an injury, it is obvious that we cannot have inflammations so divided. It is hardly possible to conceive of an injury which will affect exclusively one or the other of these constituents of an organ. There is no doubt that under certain circumstances there may be accumulations of cells in the interstices of an organ due to growth of the intercellular tissue, as in some of the pathological conditions met with in the kidneys in scarlet fever. It cannot be held that all growth in connective tissue is due to regeneration following a primary lesion. In such kidneys there are few or no lesions of the epithelium of the tubules. In certain liver diseases a similar proliferation of the connective tissue may take place. We have generally been accustomed to speak of such conditions, in which we find a cellular infiltration of the tissue, as inflammation, but there is no reason why they should be so considered. The proliferation of the connective tissue may be due to the direct action of bacteria or their chemical products on the tissue, or to other influences producing it without any preceding injury.

Inflammation of a mucous membrane is spoken of as "catarrhal inflammation." Virchow used the name to denote increase of functional activity of a mucous surface. The word "catarrhal" is used so loosely that it is difficult to define it. We may use it to designate mild degrees of inflammation of mucous surfaces in which there is neither ulceration nor any distinctly characteristic exudation, such as a fibrinous or a purulent one. In inflammation of the intestinal canal the word is generally used to include inflammations the etiology of which is unknown. The increased amount of fluid which comes from an inflamed mucous surface has two sources. In the first place, the mucous membrane has not a dense tissue on the surface impervious to fluids, like the horny layers of the skin, and an increased amount of exudation in the subcutaneous tissue readily finds its way to the surface instead of accumulating in the interstices of the tissues. A mucous surface is like a serous surface in this respect. In the next place, the proper secretion of the mucous surface is increased. This is in part due to the hyperæmia of vessels supplying the glands, and possibly in part to a direct stimulation of the glands by the inflammatory cause. The cells may be influenced to increased action in the same way as the blood-vessels are. In most cases the serous exudation from the vessels of the tissue

is accompanied by emigration, and the leucocytes pass as readily through the epithelial layer as does the serum, and appear in the fluid on the surface.

A more suitable classification of inflammation is one based on the character of the exudation. The character of the exudation is largely determined by the cause of the inflammation and the intensity of its action. The causes are so manifold that it would be impossible to give an etiological classification. The exudation in inflammation may be almost entirely serous, and such inflammations are spoken of as œdematous or serous inflammations. In any inflammation the quantity of serous exudation is increased. The tissue in serous inflammation is infiltrated with fluid. The increased transudation represents the reaction of the tissue to a mild injury. One of the best examples of it is the inflammation of the skin which follows prolonged exposure to the sun. The injection of the vessels is extreme and the skin is swollen and pits on pressure. Most of the exudation accumulates in the meshes of the tissue, but a certain portion passes to the surface and elevates the epidermis in the form of smaller or larger vesicles. The vesicles are filled with a clear transparent fluid which on microscopic examination shows few cellular elements. If the cause be removed, the contents of the vesicles will be absorbed. The action of the sun has probably been to produce slight injury of the upper layers of the epidermis, in some cases extending more or less deeply into the tissues below. In some cases extensive necroses extending through the skin, which are followed by all the phenomena of intense inflammation, may be produced. There is increased serous transudation in the beginning of every inflammation. In pneumonia, congestion and œdema of the lung precede the formation of the fibrinous exudation. In every wound a clear fluid first exudes which contains but few corpuscles, and which, coagulating in a thin layer on the surface, produces the glazing. The œdematous inflammation may also represent the end or limit of the process. In a furuncle, outside of the central necrosis and leucocytic infiltration, the tissues are infiltrated with serous fluid, and a subcutaneous œdema is often found accompanying acute inflammation of the costal pleura.

In any inflammation there is an increased amount of fibrin in the exudation as compared with the normal (Fig. 5). The fluid in the tissue in œdematous inflammation contains more fibrin than when the exudation is increased from some other cause, as from chronic passive congestion. The fibrin may accumulate in the tissue and give rise to a dense, brawny induration. The amount of fibrin is to a certain extent dependent upon the severity of the inflammatory cause of the injury. As a general rule, the greater the degree of necrosis the more extensive will be the formation of fibrin. The elements for the formation of fibrin are present in the exudation, and the necrotic cells supply the fibrin-ferment. To a much greater extent the formation of fibrin seems to depend upon the nature of the agent which produces the inflammation. The most typical fibrinous inflammation is seen in acute croupous pneumonia. Even in the rabbit, when inoculated subcutaneously with the organism which causes this disease, a fibrinous exudation may be produced which may extend over the centre of the abdomen. It is possible that substances may be produced by these organisms which have an analogous

action to the fibrin-ferment. Such inflammations, characterized by an excessive amount of fibrin in the exudation, are spoken of as fibrinous inflammations. The term is more generally used to specially characterize fibrinous exudations on surfaces of the body. Such exudations are always accompanied by necroses, and are called diphtheritic. Formerly a distinction was made between croupous and diphtheritic inflammations. In the croupous inflammations the exudation was supposed to be seated on the surface of relatively intact mucous membranes. In the diphtheritic inflammations the exudation was supposed to extend from the surface into the meshes of the tissue. The croupous exudation could be peeled as a membrane from the surface, leaving it intact; the diphtheritic could not be removed without the production of a loss of substance. The only difference between the processes is one due to the anatomical character of the surface. In both cases there is necrosis of the surface epithelium, and the exudation, coming in contact with the necrotic tissue which furnishes an abundent supply of fibrin-ferment, coagulates. The exudation can be easily removed as a membrane on surfaces having a dense basal membrane beneath the epithelium. It is not removed from the surface of the epithelium, but is removed with the epithelium. The exudation cannot be removed from the surface where there is no basal membrane beneath the epithelium, in which case the union of the epithelium with the tissues beneath is more direct. In this case the fibrin also extends down into the tissue beneath, and there is a close union with the fibrin on the surface and that in the tissues, and it cannot be removed as a mass. The difference between the two is easily seen in diphtheria. When the disease is localized in the pharynx the membrane cannot be removed. If in the larynx and trachea, it can be removed, sometimes representing a perfect cast of these parts. The term "diphtheritic inflammation" is simply an anatomical one, and has no necessary relation to the infectious disease diphtheria. This disease is characterized by a fibrinous exudation on the surfaces affected, combined with necrosis. It is very probable that here, just as in the fibrinous exudation in pneumonia, the character of the exudation is due in great part to the specific agents which cause the disease. In some cases the membrane is much more extensive than in others, and it may be produced, though generally not to the same degree, by other agents than the diphtheria bacilli. Inflammations of the same parts caused by some of the pus-organisms, and even by the application of chemical agents which will produce a necrosis on the surface, may be accompanied by membrane-formation. The fibrin on the surface does not come exclusively from the exudation. The epithelium itself undergoes a form of necrosis which is combined with coagulation of the protoplasm of the cell, and a reticular mass is formed largely composed of the fibrinoid metamorphosis of the cells. The fibrin in these exudations does not always have the same character. In the tissues the fibrin usually appears in the form of extremely fine filaments. On the surface it may appear in the form of large hyaline masses or as a definite reticulum. In all of the mucous surfaces this form of inflammation is frequently observed. In the large intestines it forms one of the anatomical varieties of dysentery. On open wounds a fibrinous inflammation leading to the production of dense membranes is not infrequently observed. It may be due to infection of

the wound with certain specific micro-organisms. In cases of diphtheria any open wound of the body is liable to become infected with the organisms of the disease, and a typical membrane may be formed over the wound. I have seen two cases in which the infection of wounded surfaces resulted from accidental inoculation. In one there was a fissure of the anus which became so infected, and in the other a paronychia about the small toe became infected. In both the characteristic organisms were obtained from cultures. In the uterus a diphtheritic membrane with extensive necrosis of the surface forms one of the lesions found in puerperal infection. Here the condition is in nearly all cases due to the presence of one of the pus-organisms, the streptococcus. Fibrinous inflammations are also found on the serous surfaces, and they seem to take place more readily here than in any other part of the body. The fibrin is deposited both on the surface covering the viscera contained in the cavity and on that lining the walls. Where these two surfaces move over one another, as in the pericardium, the constant adhesion and separation give rise to a roughening of the surface, causing the appearance which has been compared with that produced by the separation of two pieces of bread and butter. In serous membranes the fibrinous inflammation is in part due to a greater degree of intensity in the action of whatever produces the inflammation. The same agent acting in different degrees of strength can at one time produce a simple serous exudation and at another a fibrinous exudation. When two surfaces covered with a fibrinous exudation come in contact with one another, adhesions are formed from the intermingling of the fibrillæ of fibrin on the two surfaces. In fibrinous inflammation of the peritoneum the adjacent surfaces of the viscera become adherent. The fibrinous exudation sometimes serves in this way a useful purpose in uniting wounds. The primary adhesion of a simple wound is due to this intermingling of the exudation from the opposing sides of the wound.

Hemorrhagic inflammation is spoken of when the exudation contains large numbers of red blood-corpuscles. This character of inflammation may be due to a specific action of some agent producing the inflammation, or it is due to constitutional anomalies on the part of the individual. Thus in scurvy and purpura an inflammation which under ordinary circumstances would be serous only, may become hemorrhagic. The constitutional anomaly is due either to a condition of the blood-vessels which allows the red blood-corpuscles to pass through them more readily or possibly to changes in the blood itself.

Purulent Inflammation.

This is a form of inflammation which is sharply separated from the others, and is characterized by an exudation which is called pus. In other forms of inflammation the exudations may differ, depending upon the action of different causes or upon a greater or less intensity in the action of the same cause. We can have from the same cause acting in varying degrees of intensity a serous, a fibrinous, or a hemorrhagic exudation. By subjecting the ear of a rabbit to water at different degrees of temperature all the various forms of inflammation may be

produced, with the exception of the purulent. This cannot be produced by the action of the most intense caustics.

Pus is a whitish or grayish opaque fluid of varying degrees of density. It may acquire a reddish tinge from an admixture of red corpuscles; in some cases it has a distinctly yellowish or bluish tinge, the latter being due to certain of the bacteria which cause suppuration. The exudation may infiltrate in the tissues—that is, it may be contained in the meshes of the tissues, as in the serous exudation—or it may be contained in cavities which are hollowed out in the tissues. Such a cavity containing pus is called an abscess. Or, again, there may be a loss of substance on the surface from which such a fluid exudes. In all other forms of inflammation, particularly in the more severe forms, there is more or less fibrin in the exudation. In the purulent inflammation the exudation contains either no fibrin at all or only a small amount of it. Moreover, the exudation differs in the effect which it has on the tissues of the inflamed part. In the serous and fibrinous inflammations the exudation either accumulates in the interstices of the tissue, or, if it cannot be contained in this, it passes to the surface or into the natural cavities of the body, always following the path of least resistance. The exudation in itself seems to produce no injury to the tissue. The tissue, of course, may be injured by having its nutrition interfered with by compression of vessels produced by the exudation, and very extensive necrosis may be produced in this way; but the exudation in itself produces no injurious action on the tissues with which it comes in contact. The purulent inflammation is different. In this there is not only destruction of cells by the exudation surrounding them, but the intercellular substance itself is destroyed and dissolved by the exudation. The exudation and the softening and destruction of the tissue combine to form the abscess. The dissolution of the intercellular substance takes place more easily in the loose areolar tissue. Not only is this solvent action of the exudation exerted on the intercellular substance, but the fibrin also, when any is present, is dissolved in it.

We can easily follow the course of development of an abscess by injecting some of the bacteria, which from their specific action are spoken of as the pus-organisms, into the ear-vein of a rabbit. The organisms are carried into various tissues, and by their growth form small masses in these. The first effect of the presence of the organisms is the production of necrosis in the tissue immediately surrounding them. This is accompanied by an enormous emigration of leucocytes extending into the necrotic tissue, and the leucocytes to a great extent undergo the same necrosis as the tissue. In the periphery they form a more or less distinct wall around the necrotic tissue. In the necrotic area itself there is of course no inflammation. Not only are the cells destroyed, but the blood-vessels as well, and no circulation takes place within the part. The next stage in the formation of the abscess is the liquefaction of the tissue. The bacteria or their chemical products appear to exert an actual dissolving power on the tissue. First, apparently, the intercellular substance is dissolved, and all of the cells, both those of the tissue and the leucocytes, come together to form a single mass. Sometimes the tissue-cells more or less retain their form and can be recognized, but more often they are broken up into fragments or granules. In some cases the suppuration

does not spread from a single point in this way, but from several adjacent points. Then the various foci of softening come together, forming a single cavity, which may contain not only the individual cells which have been set free by the dissolution of the intercellular substance, but larger masses of tissue into which the softening has not fully extended, and which are set free by the various foci of softening meeting one another. The various tissues show a varying resistance to this softening power of the exudation. In a glandular organ the connective-tissue septa in the gland offer the least resistance. The suppuration may extend along these, and an abscess be formed which will contain large necrotic masses of the glandular substance. Such masses are spoken of as sloughs.

The pus varies in consistence. Sometimes it is thick and creamy, at others it is thin and similar to a serous exudation. The cells are to a large extent the white corpuscles of the blood. Of course along with these cells there will be other cells and fragments of cells which come from the tissues. When the pus-cells are examined on the warm stage of a microscope many of them show active amœboid movements. The fluid portion of the pus is simply the serous exudation. The pus contained in a definite abscess-cavity is frequently under considerable tension, sometimes apparently much higher than the blood-pressure. On

FIG. 6.

Section of a chronic abscess of the lung: *a*, layer of granular material composed of necrotic cells and bacteria; *b*, layer of tissue filled with leucocytes; *c*, loose granulation tissue containing dilated blood-vessels, from which active emigration is taking place; *d*, denser cicatricial tissue.

making an incision into an abscess the contents may spurt to a considerable distance. When the abscess-cavity has remained for some time a definite wall is formed around it, which prevents its further extension (Fig. 6). As the abscess is forming there is constantly going on outside of the necrosis and outside of the wall of leucocytes a growth of the tissue. All of the cells of the tissue, the connective-tissue cells, those forming the walls of the blood-vessels, and probably also the specific cells of the tissue, proliferate. In consequence of this proliferation there is produced a dense tissue consisting to a large extent of cells

similar to the lymphoid cells of the blood. This is the same tissue which forms the small projecting granules seen on the surface of an ulcer, and from this it has received the general name of granulation tissue. Sometimes softening does not take place until such a definite wall is formed around the focus. This action on the part of the tissue varies in different cases. Sometimes it is almost entirely absent, and there is nothing opposed to the extension of the process. In some cases it would appear as though there were a direct excitation of cell-proliferation of the tissues produced by the bacteria. Such a membrane lining an abscess is called a "pyogenic membrane." It is a soft reddish membrane having a slight similarity to a mucous surface. It was formerly supposed that pus could be directly secreted by such a membrane. It always contains, along with the cells derived from the tissue, a large number of leucocytes, which are constantly passing through it into the abscess, and in the vessels not only of the membrane itself, but in those of the surrounding tissues, there are quantities of leucocytes. In many cases the membrane does not offer sufficient opposition to the advance of the suppurative process. The cells composing it may become necrotic, soften, and form part of the contents of the abscess, and its formation gradually recedes as it is gradually destroyed. There is no sharp limit to the membrane-formation, but it gradually fades off into the surrounding tissues. For a considerable distance around, the formation of granulation tissue continues, appearing as an infiltration of the interstitial tissue with small round cells. Sometimes the purulent inflammation is preceded by a fibrinous or serous inflammation. The fibrinous inflammation of a serous surface may become changed into a purulent, and the fibrin which has been formed becomes dissolved in the pus. There may be a large amount of fibrin in the tissue surrounding an abscess which may become softened by the advance of the suppuration.

We may distinguish various sorts of abscesses, depending on the character of the pus and the character of the tissue in which it is formed. When an abscess forms rapidly and is accompanied by a considerable amount of pain and evidences of acute inflammation, it is spoken of as an acute or a hot abscess. On the other hand, the abscess-formation may take place slowly, the pus may accumulate slowly, and, if this takes place in an organ poorly supplied with nerves, it may not give rise to any special symptoms. Again, the pus may be formed in one portion of the body, and may by gravity extend into a portion lower down, gradually dissolving the tissue as it passes along. Such an abscess is called a cold or gravity abscess. One of the best examples of this is the abscess which appears in the inguinal region, the pus being formed in the vertebræ and descending along the psoas muscle.

The amount of pain in purulent inflammation differs greatly. In some cases it is intense; it others it may be entirely absent. This depends largely upon the character of the tissue and the amount of nerves in the part. In an abscess of the subcutaneous tissue, where pressure is exerted on the nerves of the skin, the pain may be intense. In abscesses in internal organs poorly supplied with nerves, as in the liver, a large abscess may be formed without any pain accompanying it. The pain will also, as in an ordinary inflammation, depend upon the amount of pressure which is exerted on the nerves. In a tissue capable

of distention there will be less pain than in a firm, dense tissue. Abscesses of bone and of the periosteum are accompanied by intense pain. The amount of pain will also depend upon the rapidity with which the abscess is formed. If the pus accumulates rapidly, the pain will be more intense; if it accumulates slowly, the tissues can gradually become accustomed to the distention.

Inflammation produced by Bacteria.

The action of almost all pathogenic bacteria is closely related to inflammation, because such bacteria in general produce an injury to the tissue where they are present. The inflammations which are produced by bacteria are also in some ways different from the chemical or mechanical inflammations. Bacteria may act on the body in a variety of ways. In the first place, the organisms may enter directly into the blood, and there find suitable conditions for their growth, or, without growing in the blood, may be deposited by it in the different organs. In most cases there is a primary lesion produced, and the infection of the blood follows from this. In consequence of this the bacteria may be deposited in the various organs of the body, and foci similar in their general nature to the primary focus of infection may be formed. A distinction must be made between the cases in which the organisms grow in the blood and the cases in which they may enter the blood, but do not find there suitable conditions for their growth, and the blood simply acts as a carrier, depositing them in various organs, where they exert a local action. When the organisms enter into the blood the condition of septicæmia is produced. Many of the pus-organisms have the power of infecting the blood, and septicæmia is most frequently found as an accompaniment to some one of the purulent affections. In many cases the danger of septicæmia seems to stand in inverse relation to the extent of the primary infection. The more developed the local infection, the less apt the septicæmia is to take place. Frequently the same organism which causes a typical local disease in one animal will produce septicæmia in another. In man inoculation with the anthrax bacillus will always produce an intense local inflammation at the point of inoculation, the anthrax pustule, which is only exceptionally followed by septicæmia. Most of the local lesions produced by bacteria are distinctly inflammatory in character. This is eminently the case in most of the acute infectious diseases; for instance, in anthrax, in diphtheria, in pneumonia. Many of the inflammations so produced are purulent in character. In other cases lesions very closely related to inflammation, or which at some period of their course are accompanied by inflammation, will be produced. The lesions which are produced by the tubercle bacillus and by the typhoid bacillus are at first not inflammatory in character. The lesions consist in a new formation of tissue of a definite type, which arises from proliferation of the fixed cells of the tissue. In the beginning of these formations there may be no emigration of leucocytes and no inflammatory lesions in the tissue. At a later period, however, in each, necrosis and degeneration take place in this newly-formed tissue, and with this the inflammatory phenomena begin. In typhoid fever the lesions, in the first place, consist of a new formation

of lymphoid tissue arising from the lymphoid tissue of the intestinal canal. In this lymphoid tissue there are no leucocytes, and, although there may be hyperæmia of the surrounding blood-vessels, there is no emigration of leucocytes and no increased exudation. It is only when necrosis takes place in the hyperplastic tissue that the invasion of leucocytes begins. The same is true in tubercle. Emigration only begins and leucocytes are only found in the tuberculous tissue when caseation appears. The necrosis which arises in a specific tissue in this way apparently has the same attraction for the leucocytes as has necrosis of normal tissue. The same thing is true of the new formations not caused by bacteria. Many of the tumors are accompanied by inflammation in the surrounding tissues, and even in the tumor itself there may be emigration, an increased exudation from the blood-vessels; and this is closely connected with processes of degeneration in the tumor. These processes may be related to inflammation in another way. Thus the tubercle may excite inflammation merely by its presence. It may produce by its presence injuries in the tissue which will be followed by inflammation, and which may not be immediately connected with the bacteria.

The character of the inflammations produced by bacteria will be largely influenced by the manner in which these gain entry into the system. This may take place in various ways. They may enter into the tissues, producing an inflammation at the point at which they enter, or they may produce no local lesions at the point of entry, and be carried by the blood to various tissues of the body and deposited there, only producing lesions in the tissues for which they have a specific affinity, which is probably due to the fact that certain tissues offer them the most suitable conditions for their growth. This is the case in small-pox and in scarlet fever. Although we do not know anything about the virus of small-pox or of scarlet fever, it is exceedingly improbable that the lesions of the disease could be produced by bacteria finding entry through the skin. The same bacteria do not always act in the same way. In general we are able to surmise from the character of an inflammation what is the specific organism which has caused it; but there are exceptions to this. The same organism which causes a typical fibrinous inflammation in the lungs may under some circumstances produce a distinctly purulent inflammation without any formation of fibrin at all. One of the pus-organisms, the streptococcus, may produce in the pharynx as typical a fibrinous inflammation as is produced by the diphtheritic bacillus, while under other conditions it may form an abscess. The bacteria may also be related to inflammation in another way. They may produce local lesions, and there may be produced in these local lesions chemical poisons which will produce necrosis and degeneration in distant organs, and these may be followed by inflammatory phenomena. The most typical inflammations are produced by a group of organisms which are so closely related to suppuration that they are called the pyogenic or "pus-organisms." Suppuration may under certain circumstances also be produced by a number of other organisms. The essential pus-organisms are the *staphylococcus aureus*, the *streptococcus pyogenes*, the *staphylococcus epidermidis albus*, the *bacillus pyogenes fœtidus*, and the *bacillus pyocyaneus*. In addition to

these suppuration has frequently been found to be produced by other organisms; for instance, by the colon bacillus, by the tubercle bacillus, by the *diplococcus lanceolatus*, by the *bacillus proteus*, and by various others. The most typical purulent inflammations are those produced by the staphylococcus and the streptococcus. In the case of the staphylococcus its action has been thoroughly investigated by experiments both on man and animals. The most typical inflammation in man produced by it is the ordinary boil or furuncle. In this it is evident that the bacteria find their way into the skin along the hair-follicles or the sebaceous glands. It has been found that the mere application of the organisms to the surface of the skin is not followed by any results. When they are rubbed into the skin the typical furuncle may be produced. They apparently do not enter into the skin by means of the sweat-glands, and furuncles do not appear on the parts of the body where there are no hair-follicles or sebaceous glands, as on the palm of the hands or the soles of the feet. They are most apt to appear on portions of the body which are subjected to the rubbing of clothing, as at the back of the neck and the waist-line. There is first produced a necrosis of the tissue in the neighborhood of the hair-follicles or gland, and around this suppuration. The necrotic tissue which produces this does not always liquefy, but remains as the so-called core of the furuncle which is cast out with the pus. The pus produced by the staphylococcus, as a rule, is thick and creamy, frequently with a distinctly yellowish color, probably due to the pigment produced by the organisms in their growth. The streptococcus has a greater variety in its action than the staphylococcus. The streptococcus may produce on the surface of mucous membranes a typical fibrinous exudation, or it may produce suppuration of the tissues. Its action, even in producing suppuration, is not circumscribed, as is the action of the staphylococcus. Typical suppuration with liquefaction of the tissues is not so apt to be produced, and the pus has not the thick creamy character of that of the staphylococcus. In many cases no suppuration at all is produced, but simply an infiltration of the tissue with serum and leucocytes. When suppuration is produced by the *streptococcus pyogenes* it usually takes the form of purulent infiltration. Streptococci may be found in the tissues even outside of the line of leucocytes, and they do not produce so much necrosis, nor do they themselves exert such a positive chemotaxis, as do the staphylococci. Both the streptococci and staphylococci may produce on serous surfaces extensive suppuration. On both serous and mucous surfaces the inflammation produced by the streptococci is accompanied by a greater formation of fibrin. The inflammations produced by the streptococci are, as a rule, far more dangerous in their local and in their general effects than those produced by the staphylococci. Inflammation of the uterus in puerperal fever is almost always due to the action of the streptococci.

Inflammations produced by bacteria show in one way a vast difference from those produced by the action of chemical and mechanical causes. In inflammation produced by mechanical causes the action of the cause ceases with the inflammation. It is impossible that it should extend to other parts of the body. The bacteria may be in various ways carried from one portion of the body to another, and wherever they

come they produce the same character of inflammation as in the primary focus. Those inflammations which appear in the different portions of the body following a primary focus of inflammation are called secondary or metastatic inflammations. The organisms may pass along the course of the lymphatics, either producing inflammations in places connected immediately with the primary focus by means of the lymphatics, as the lymphatic glands, or they may be carried by the lymphatics into the blood and then into other organs. They are most apt to be retained in the nearest lymphatic glands and excite these to inflammation and suppuration. As an example of this we have the buboes in the groin which follow local processes in the external genitals. The lymphatic glands may also be excited to inflammation by other products than the bacteria. The chemical products which are produced in the inflammatory focus are washed out by the exudation and carried by the lymphatics to the lymph-gland, where they may excite inflammation. Such inflammations are rarely followed by suppuration, and the changes in the gland more generally consist in hyperplasia and the formation of a new lymphoid tissue.

When the organisms enter into the blood they are carried into all of the organs and tissues of the body. But there is a decided difference in their action in the different tissues. Certain of the tissues are more liable to have these secondary abscesses following on blood-infection than others. When the staphylococcus aureus is injected into the ear-vein of a rabbit, the metastatic abscesses take place in different organs. The organisms of course first find their way into the blood-vessels of the lungs, but here it is extremely rare that we ever find any lesions produced by them. The secondary foci of inflammation, the abscesses, are generally limited to the kidney and to the myocardium. They may also develop in the muscles of the body, but here, again, the preference is shown for certain regions. The muscles most frequently attacked are the abdominal muscles. It is difficult to explain this. The frequency with which certain organs are attacked may be due in large part to special differences in the circulation of these organs. In both the kidney and the heart the arteries are terminal; that is, each portion of the tissue is supplied by a distinct artery without anastomoses. The same condition obtains in the spleen and in the brain, but abscesses only rarely develop in these parts. It cannot be due to the greater facility with which the organisms are deposited in certain organs. All sorts of very finely-divided foreign bodies entering into the blood are deposited with greater facility in the liver than in any other organ, because here there is an enormous system of capillaries with very slow circulation. It is probable that the organisms find in the tissues of certain organs more favorable conditions for development than in others. The organisms appear to be rarely carried as large embolic masses plugging up blood-vessels. In the kidney there is little doubt but that they do act partly in this way, and the effect of their specific presence may be accompanied by the mechanical effects of infarction. They are not carried as embolic masses, because, even if they were injected as such into the veins, they would not be able to pass through the blood-vessels of the pulmonary circulation. In the kidney their action has been closely studied by Ribbert. It is probable that they lodge in or are taken up

at some point in the circulation by the endothelial cells of the small arteries, and by their continuous growth they may plug up the vessel, and from this primary focus they may be carried as masses into smaller branches of the same artery.

The secondary inflammation may be produced in another way. The bacteria may find entry into the tissue along various ducts or canals which lead from the primary focus into other portions of the body. The most typical example of this is given in the secondary abscesses which develop in the kidney following a primary purulent inflammation of the bladder or of the urethra. The organisms make their way from the bladder into the kidney in a direction opposed to the flow of the urine. It is probable that their progression is due to a gradual growth along the wall of the urethra and of the pelvis of the kidney. They may do this without producing any inflammation of the urethra, but most often there is a general inflammation of this; or it may be that they find suitable conditions for growth in the urine in the urethra, and infection may follow in this way. Rinne includes among the metastatic abscesses those produced by the action of bacteria which enter the body without producing any lesions at the point of entry, and are often carried into remote organs, where their action takes place.

There is the greatest diversity in the effects produced by the pyogenic organisms. This is due to a number of factors, and, although much light has been thrown on the matter by experiments on animals, there remains much which is not at all or imperfectly understood. As a result of the entry of the same organism into the system there may be no effect produced; or there may be a slight inflammation not leading to suppuration or more or less extensive abscess-formation; or without definite abscess-formation an extensive and diffuse purulent infiltration of the connective tissue; or without the production of any local lesions there may be a general infection of the blood, and death may take place in two or three days with the phenomena of an acute intoxication. I saw during the last year a case in which a surgeon died several days after an operation on a case of peritonitis. There was no history of a wound received at the time of operation, and no definite point of entry for the organisms could be found at the autopsy. The most extensive lesions were in the right thigh and extended from this up to the buttocks. Over these parts there were large blebs and partial desquamation of the epidermis. The subcutaneous tissue and the adjacent muscles were necrotic and contained masses of streptococci. The same organisms were obtained in pure culture from the blood and from every organ of the body. The infection very probably took place from the thigh, and the organisms possibly entered from a scratch with the nail or in some such way. There was no definite suppuration, and in the necrotic tissue of the muscle there were but few leucocytes.

In any attempt to explain such variation in action the resistance of the tissue must be considered. This resistance is due to a number of things. The blood-serum is directly destructive to a number of organisms, and when they are subjected to its action, in some cases for a few hours only, they are destroyed. Also, there is no doubt that the leucocytes play a most important part in destroying the bacteria, in preventing their absorption, and in warding off their action from the sur-

rounding tissue-cells. It is probable that this action of the leucocytes is not the only way that the body has of combating the organisms, but it plays an important part. Different animals have different degrees of susceptibility to the action of bacteria. It is probable that this is largely due to differences in the destructive powers of their serum. The number of organisms which are introduced into the body has an important influence. This is shown by the results of the injection of the staphylococcus into the ear-vein of a rabbit. If the organisms injected are of the same degree of virulence, the effect produced is largely dependent upon the amount of the culture which is injected. Very small doses may produce no effects. The tissue into which the organisms are introduced is of importance. After the injection of the staphylococci into the ear-vein of a rabbit abscesses are developed in certain organs only, and this cannot be explained by the organisms entering these organs only, for other organs are equally exposed to their action. The same thing is seen in the direct injection of the organisms into the tissue. The smallest drop of a pure culture of the staphylococcus injected into the anterior chamber of the eye of a rabbit is sufficient to develop an extensive suppuration, with loss of the eye. A much greater quantity is necessary to produce an abscess when the injection is made into the loose subcutaneous tissue of the back than is required when the injection is made into the dense tissue of the ear or into the muscles. This is probably in part due to the greater ease of absorption in the several places. When the absorption is rapid the bacteria can be taken into the blood, and there be destroyed by the serum without time being given for their local action in producing necrosis of the tissue and chemical poisons. Grawitz has shown the importance of absorption in his work on the production of peritonitis in the dog. This animal possesses to a high degree immunity to the action of the staphylococcus. Large quantities of the organisms may be injected into the peritoneal cavity without any effect, provided the tissues are normal. If the power of absorption be in any way interfered with, or if the serous surface be stripped off over a small area, general purulent peritonitis results. Halsted has shown that the same thing is true when, instead of a fluid culture, a piece of potato with a growth of the organism on its surface is placed in the cavity. In this case a fatal peritonitis is always produced. The potato has nothing to do with the result beyond affording a suitable place for the development of the organisms and allowing them to produce their chemical poisons. The potato without the organisms becomes rolled up in the omentum and encapsulated. If an emulsion of agar with the organisms growing in it be injected beneath the skin, it is more surely followed by suppuration than when the culture is injected in a fluid medium. One of the main elements seems to be the action of the soluble chemical poisons produced by the organisms. If the injection is made into a dense tissue, the organisms may find a suitable soil for their development, or they may create it by the production of necrosis in the surrounding tissue. The poison which they create may not only inhibit the local resistance of the tissue, but when it is gradually absorbed it may destroy the germicidal power of the entire blood-current. In any case it is of the utmost importance to oppose to the action of bacteria as normal tissues as possible. It is probable that a great deal of the

result of modern methods of surgical technique is due as much to the greater care bestowed upon wounds as to the care exercised in excluding bacteria.

Differences in the virulence of the organisms play an important part in their effects on the tissues. The pus-organisms are not definite chemical compounds, and they vary enormously in their virulence. This virulence is gradually lost in the cultures. It remains longer in the staphylococci than in the streptococci. A few generations of cultures may suffice to destroy the virulence of the streptococci completely. In the staphylococcus aureus we can to some extent estimate the degree of virulence by the intensity of the color which is produced. The source from which the organisms are derived is also of importance, as is also the fact whether the organisms are injected alone or accompanied with toxic substances. The various accompanying toxic substances must play a great part in the purulent infections as they occur under natural conditions. In natural infection we have to do, not with pure cultures of the pyogenic cocci, but with organisms which have come from all sorts of sources and have been growing in various conditions, and which are frequently mixed with many kinds of bacteria. There is proof that under some of these conditions the infectious material may acquire a degree of virulence which we are not familiar with in artificial cultures. Bumm found that injection into the peritoneal cavity of a rabbit of a fraction of a drop of the fluid from a case of acute puerperal peritonitis produced acute peritonitis in the animal, whereas pure cultures of the same organism were nothing like so virulent. Fehleisen found that a pure culture of the *staphylococcus aureus* to which he had added a little of the clear fluid from the inflammatory œdema of a spreading cellulitis was far more virulent than the ordinary culture.

Any condition of the system which lowers its general resistance will increase the action of the pus-organisms. It has been found that suppuration is more easily excited and is more intense in animals which have been rendered anæmic. Even when local anæmia is produced by tying or constricting an artery, the suppuration following inoculation with the same amounts of the organisms is more severe on the anæmic side than on the normal. If the blood is rendered hydræmic, the effects of inoculation are increased.[1]

Some of the infectious diseases render the tissues more liable to the effects of the pyogenic organisms. This has been shown in typhoid fever. An old focus of inflammation may become purulent when the resistance of the tissues is lowered by disease. Not only may the general resistance of the body be overcome, but the local resistance as well. Various local injuries of the tissues have been produced, and then organisms injected into the circulation, and it has been shown that in many cases the organisms have settled in the injured tissues and have there produced a purulent inflammation. Sometimes the presence of other bacteria increases the action of the pus-organisms. Trombetta has shown that when cultures of the staphylococcus were mixed with the prodigiosus the effects were increased. The tubercle bacilli and the typhoid and other organisms when mixed with the staphylococci have

[1] Welch: *Conditions underlying the infection of wounds.*

the same effect. The resistance of the tissues is undoubtedly lowered when chemical products of the bacteria are introduced along with them. In any case it is probable that the diminished resistance of the tissues is due to changes in the blood, and consists chiefly in destruction or diminution of the germicidal power. The presence of such chemical products of bacteria may also prevent the establishment of leucocytosis. While it is probable that in man the injection of even a large number of pus-organisms in the normal blood would have little or no effect, the condition is different when the organisms enter into the blood after its germicidal power has been weakened by absorption of poisons from the local suppuration. Metastatic abscesses do not develop early in the course of a suppuration, but at a late period when the blood has been poisoned by absorption. They are not due alone to the organisms. Even dead organisms when injected into the tissues in sufficient quantities may excite suppuration, for the protoplasm of the dead bacteria is a powerful agent in attracting the leucocytes.

In speaking of suppuration, so far, we have only considered it in relation to the bacteria. For all practical purposes that is the only way in which it need be considered. All of the suppurative processes which we meet with in man are due to bacteria, and they may be obtained either in cultures made from the pus or on microscopic examination of the tissues. If the cultures made from an abscess are sterile, that is no proof that the suppuration was not produced by bacteria. The organisms may be dead or they may not grow on the medium which was used for culture. Other organisms than the bacteria may excite suppuration. It is known that some of the protozoa have this action. The *amœba coli* when it enters into the liver from the large intestine will produce abscesses, and it has been found to be the cause of abscess-formation in other places. Flexner has reported a case in which an abscess of the jaw was produced by this organism.

It is certain that typical suppuration may be produced by chemical substances, but abscesses so produced are not often met with. There has been a great deal of experimenting done on this question, and it may be regarded as established in the affirmative. Croton oil is one of the most certain substances to produce suppuration when injected into the tissues. In a series of experiments croton oil was enclosed in thin glass capsules which were previously thoroughly sterilized. These were placed beneath the skin of rabbits, and after several days, in every case after the wound was thoroughly healed, they were broken from without. In every case a typical focus of suppuration was produced. It has long been known that when croton oil is rubbed into the skin a crop of small pustules will result. Turpentine and a few other substances will produce suppuration, but not so certainly as will croton oil. There is no reason why some of these substances may not do this. They are caustics, and when they come in contact with the tissues they will produce necrosis; and they probably have in themselves, or they assist in forming in the tissues, substances which have the power of dissolving the necrotic tissue and the fibrin.

Not only the purulent inflammations, but inflammations of any sort, are affected by the condition of the body, and especially by local or general pathological conditions of the circulation. For the preservation of

the normal condition of the tissues a normal circulation is necessary. The blood must flow through the tissues in the proper amount, with the proper pressure, and the quality of the blood must not be altered. A change in any one of these conditions or all of them has an important influence in modifying the course of inflammation. We have already spoken somewhat of the influence of anæmia in modifying the purulent inflammation. When the central artery of the ear of a rabbit is ligated, sufficient blood will enter the ear by the small arteries on the edge of the ear to preserve the integrity of the tissues. If, however, after ligating the central artery the ear be exposed to influences which in normal circulation would result only in a minor degree of inflammation, a much more severe type, frequently ending in necrosis of the entire tissue, will be produced. Samuel has shown that the exposure of the ligated ear to water at a temperature which would only slightly affect the part in a normal circulation will be followed by necrosis. In a more extensive series of experiments in parts subjected to various degrees of vascular disturbances he found that in anæmic parts all the phenomena of inflammation developed more slowly and ran their course in a much longer time. The congestion of the tissues comes on more slowly, is more extensive, and there is a tendency to coagulation of the blood in the dilated vessels, producing complete cessation of the circulation.

The course of inflammation is also modified by active arterial hyperæmia. Danilewski first studied this by exposing both ears of a rabbit to the same injurious influence after section of the sympathetic on one side. He found there was a marked difference in the course of inflammation in the hyperæmic ear as compared with the other, and the process took a more rapid and ran a more favorable course. He, however, made the mistake of regarding the ear not operated on as being in a normal condition. It is now known that after section of the sympathetic the hyperæmia of the ear on the side which is cut is accompanied by anæmia of the ear on the uninjured side; so that he really compared inflammation in a hyperæmic part with inflammation in a somewhat anæmic part. Samuel afterward studied the same subject more carefully, and found that in a hyperæmic part a more severe type of inflammation followed the same degree of injury and lasted longer. The exudation is more abundant, the swelling is greater, and all of the phenomena are more active. After the inflammatory dilatation of the artery it does not so quickly return to the normal calibre in the hyperæmic ear as in the normal.

Still more unfavorable are the conditions when inflammation takes place in a part in which there is chronic congestion. Here the quantity of the blood is increased, but, owing to the slowness of the circulation, the tissues are placed in an abnormal condition. The part can, as in the anæmic part, preserve its integrity under the ordinary conditions of life, but slight influences will be more easily felt. The blood flows more slowly through the part, the blood-vessels themselves are dilated, and the tissue lives on a lower plane. Its reserve force, its capacity for repair, is diminished. Not only will a slight cause produce a more severe type of inflammation, but the inflammation will run a much longer course and repair take place more slowly. Inflammation of this character is spoken of as hypostatic inflammation, and a good example

of it is seen in the inflammation of the posterior part of the lung which comes on in the course of various diseases when the patient has lain for a long time on the back. The ordinary effects of hypostasis in such cases are increased by weakness of the circulation due to diminished force of the heart's contraction, and the blood itself is also altered. The cause of the inflammation in such cases is usually the stagnating secretion of the bronchi, in which infection may take place.

Another example is seen in the inflammation of the leg in chronic passive congestion due to local or general impairment of the circulation. In this condition a slight blow or other form of injury which would not be felt, or only slightly, under normal conditions, will be followed by extensive inflammation, which may not heal until the part be placed in a condition more nearly approaching normal. This can be done by elevating the leg and removing the influence of gravity.

Not only will purulent inflammation take place more readily, but any inflammation will run a more severe course in a person who is the subject of general anæmia. Other conditions—as diabetes, for instance—have a marked influence on inflammation. In diabetes the inflammation tends to assume a necrotic character. It is probable that in diabetes the germicidal powers of the blood-serum are greatly diminished. Infection with the pus-organisms takes place more readily and is more severe. The primary cause of inflammation being injury to the tissue, however brought about, we can see that a tissue placed in an abnormal condition cannot so easily guard against an injury, and a slight cause will be followed by a greater effect. The inflammation will persist until the integrity of the tissue is restored, and this will take longer when the conditions for the nutrition of the tissues are not so favorable. Sometimes a tendency to certain sorts of inflammation seems to be inherited. In some persons, even when the circulation and nutrition seem to be perfectly normal, inflammation is more easily excited in certain organs and takes a more severe course. Thus an individual may be predisposed to inflammation of the air-passages and other parts of the body. In this case it is not the inflammation itself which is inherited, but a weakness or lack of resistance of the body. What this is we are unable to define. It may be, as Cohnheim suggests, an abnormal condition of the blood-vessels of the part. It seems in many cases to be local and not general. In some cases there appears to be a general weakness of the tissues inherited. There may be an inherited lack of resistance to certain causes of inflammation or to inflammation generally. Individuals with an inherited tendency to tuberculosis frequently show a general lack of resistance to all sorts of inflammatory causes.

Repeated attacks of inflammation in the same part render it more liable to inflammation. This is due to an abnormal condition of the part caused by the repeated attacks of inflammation. At each attack of inflammation the tissue may not be completely restored, and finally an abnormal tissue, one of lower resistance, is established. The tissue is then placed in the same condition as when subject to anæmia or any other disturbing influence. It can only preserve its normal condition under ordinary circumstances. The tissues are more vulnerable, and a cause which would not be felt in a normal tissue may produce a degree of injury in this which cannot be overcome without inflammation.

It is not necessary to consider at great length the differences between acute and chronic inflammation. The phenomena of inflammation vary in duration and last until the tissue is brought to a normal state. In general, the difference is due to the length of time that the cause of inflammation continues. A sudden injury of the tissue, in which the cause is removed as soon as the injury is effected, is followed by active inflammatory phenomena, which will also subside when the cause—that is, the injury which has been produced on the tissues—is removed. In some cases the injury may take place more slowly, and the injurious agent, whatever its character, may act continously, and the phenomena of inflammation develop more slowly and continue for a longer time. In these cases we have the process of repair, the attempt of the tissues to return to a normal condition, going on at the same time that the injurious cause is still acting, and the phenomena which we are accustomed to regard as typical of inflammation—*i. e.* heat, redness, swelling, and pain—develop so slowly or may be so slight as to escape our attention entirely. These chronic inflammations are frequently due to bacteria, which may extend their action not only to the tissues into which they first enter, but may continously affect the new tissue which is produced in the repair.

Another variety of inflammation is the so-called trophic inflammation supposed to be due to trophic disturbances. It is assumed by those believing in this that there is a direct nervous influence acting on the nutrition of the tissues, independent of the influence of the vasomotor nerves. The nutrition of each cell is supposed to be directly influenced by the nervous system, and the nerves governing this nutrition are spoken of as trophic nerves. Physiologists in general and pathologists do not believe much in this, and the arguments advanced in favor of the view have generally come from clinicians. As an example of such so-called trophic inflammations we may cite the inflammation of the cornea which follows section of the trigeminus. Magendie first observed that after section of this nerve inflammation of the cornea, with ulceration and destruction of the entire eye, generally takes place. There may also be inflammation of the lips and other parts supplied by this nerve. It has been also observed that after section of the pneumogastric pneumonia, frequently terminating in gangrene, develops. Another example of trophic inflammation is found in the perforating ulcer of the foot which develops in certain diseases of the spinal cord. In most cases a definite proof has been given by experiments that these inflammations do not take place when other injurious influences resulting from the section of the nerve are excluded. The inflammation of the cornea after section of the trigeminus is the result of the action of particles of dust and other foreign substances which the eye in its anæsthetic condition is no longer able to guard against. It is possible to remove the effect of the action of such traumatic influences on the cornea by sewing the edges of the lids together or by fastening one of the animal's ears over it. Von Gudden took newly-born rabbits and sewed the edges of the lids together, producing a perfect union. After the wounds were healed and the eyes absolutely sealed he cut the nerves, and on opening the eyes fifteen days after the nerve-section he invariably found the cornea normal. The inflammation of the lungs which follows section of the pneumogastric is due to the presence of particles of food and other foreign substances

which have been aspirated into the bronchi. Paralysis of the glottis is produced by the experiment, and the most simple way of preventing inflammation is to keep the animal experimented on in the dorsal position and thus prevent foreign substances entering into the glottis. Such lesions as perforating ulcer of the foot and the various joint diseases which occur in the course of certain diseases of the spinal cord are extremely rare in patients whose circumstances enable them to avoid over-exertion in the later stages of the disease and to observe every needed care. It is easy to see how this idea of trophic inflammation may have arisen. The tissues are placed in an abnormal condition. Not only is there anæsthesia of the tissue, but the circulation in the part is more or less disturbed. Thus, in paralysis, extensive ulceration (the so-called bed-sore) is frequently developed over the sacrum and other prominent bony eminences. This is due to a variety of conditions—to the anæmia which is produced by pressure and to the action of the urine and fæces which are frequently involuntarily passed by the patients, and unless the greatest care is exercised the parts in question come in continuous contact with them. The epidermis over the part will be macerated off, and the tissue beneath, whose vitality is already impaired, will be exposed. In consequence of all of these conditions the tissue becomes necrotic and large ulcers will form. Such bed-sores can always be prevented by proper care and cleanliness, and in general we may regard them as due not to trophic disturbances, but to bad nursing. Cystitis until comparatively recently was considered to be one of the symptoms of inflammation and of injury to the spinal cord. It is now regarded as a complication easily prevented by the use of clean catheters introduced with care.

There seems to be much more proof in favor of regarding some of the herpetic affections as due to trophic influences. These develop in the skin over the area supplied by certain nerves, and it has been found in some cases that the nerves or the ganglia from which they arise are inflamed. Samuel suggests the possibility that these inflammations may be due to an intense hyperæmia of the part brought about by the paralysis of the vasomotor nerves. Strümpel suggests the probability that the inflammation in herpes zoster may be infectious and due to a definite cause. One argument in favor of this is the frequent appearance of herpes zoster in an epidemic or endemic form. Pfeiffer thinks that in these cases the inflammation should be regarded as an infection which follows along the course of the intercostal nerves. The nutrition of parts is undoubtedly affected by nervous influences, and integrity of the nerves is necessary to keep the tissue in a normal condition. No part receives continually the same supply of blood, but the blood-supply is regulated according to the needs of the tissue by the vasomotor nerves. When action of these nerves is destroyed the part is simply placed in an abnormal condition as regards its nutrition, and injuries are more easily produced and less easily repaired.

A peculiar variety of inflammation is that known as sympathetic inflammation. Certain organs of the body stand in a particularly close relation with one another, and inflammation of one is followed by inflammation of the other. The best example of this is given in the infectious parotiditis, or mumps. In this the acute inflammation of the parotid gland is frequently followed in the male by inflammation of the testicles

which often reaches a severe degree, and in the female by a similar inflammation of the mammary glands and ovaries. The cause of this is absolutely unknown. It may be that the infectious agent, whatever its nature, which causes the inflammation of the parotid is localized in the other organs, or it may be that the chemical products which are produced in the inflammation of the parotid gland have a special pathogenic influence on other parts of the body. The fact that the inflammation of the other parts does not usually take place simultaneously with that of the parotid, but at a later stage of the disease, would seem to be in favor of the latter theory. There is certainly no direct nervous or vascular connection between the glands. It is only the specific infectious parotiditis which is followed by these sympathetic inflammations. Abscesses of the parotid due to the entry of bacteria into the gland along the duct are not followed by sympathetic inflammations. Another example of the sympathetic inflammation is the inflammation of one eye which follows inflammation of the other. It is only when inflammation affects certain parts of the eye that the other eye is apt to become affected. Inflammation of the conjunctiva or of the cornea is not followed by any affection of the other eye. It is only when the inflammation affects the iris and the deeper parts of the eye supplied by the sympathetic nerves that inflammation of the other eye takes place. Deutschman, who has investigated the subject by inoculating one eye with various bacteria, has thought that he could follow the course of the inflammation along the optic nerve to the chiasm, and then to the other eye. He supposes that it is due to bacteria which take this route. His experiments have been carefully repeated by Randolph at the Johns Hopkins Hospital with negative results. Against the view of Deutschman that the affection of the uninjured eye is due to bacteria is the fact that the specific infections of one eye are not followed by similar affections of the other. Thus tuberculosis of the iris and of the other parts of the eye may destroy one eye without producing any lesions whatever in the other. As a rule, it is only acute suppurative inflammations which tend to extend in this way. It is possible that the inflammation may be due to the action of specific chemical substances produced in the inflamed eye on the other. The whole question of sympathetic inflammation, however, is still very obscure.

Ulceration.

An ulcer is a loss of substance on a surface of the body. Ulceration is very closely connected with inflammation, and is frequently due to this. The ulcer really represents a part of an abscess-wall. If an abscess is seated in the subcutaneous tissue and opens on the skin, there may be continuous inflammation and suppuration along the canal which leads to the abscess-cavity, and in this way fistulæ are formed. The wall of the fistula leading to the old abscess has the same membrane which is found in the abscess itself. When the abscess is superficial, and when the opening is almost as large as the abscess itself, we do not speak of it as a fistula, but the opening together with the abscess is spoken of as an ulcer. In the ulcer there is always a loss of substance, exposing the deeper parts of the tissue unprotected by epidermis, and a chronic inflammation of these deeper parts. The ulcer ordinarily arises in

consequence of inflammation or injury which destroys the protective surface and lays bare the tissues beneath. The base and edges of the ulcer have the properties of inflammatory tissue, and in their structure are similar to tissue which lines the wall of an abscess. The base of an ulcer, as a rule, is covered with a soft reddish tissue with an uneven surface. Often the surface is covered with small elevations varying in size, which give it a granular appearance, and the small elevations are called granulations. The tissue of which the base of the ulcer is composed has received in consequence the name of granulation tissue, and the name has been extended to all similar tissues even when there are no granulations present (Fig. 7). The gran-

FIG. 7.

Dense cicatricial tissue at the bottom of an old ulcer of the leg. The blood-vessels are numerous, but are compressed by the surrounding tissue.

ulations are simply the small elevations. The same sort of tissue is found in all sorts of chronic inflammations, and the name has been extended to characterize a group of tumors closely related to inflammation which have received the name of granulomata, because their tissue is similar to the tissue found in the granulations of an ulcer. These granulations appear to be composed of projecting masses of blood-vessels with newly-formed tissue around them. Sometimes the granulations are exceedingly well marked, in other cases not. They are in general best seen in ulcers of the skin. They are not present, to any extent at least, in ulcers formed in the alimentary canal

and a deep-seated abscess-cavity does not contain them. Hamilton has advanced a rather ingenious explanation for the formation of these granulations: It is known that all liquids and tissues of the body are under a certain pressure, and the force exerted in the distention of the blood-vessels by the heart is opposed by the elasticity of the tissue around the vessels, which prevents any marked degree of dilatation. All the so-called cavities of the body, such as the peritoneum, pleura, and pericardium, have their surfaces in accurate apposition or are filled with some resisting material which counterbalances the pressure of the blood. If an inflammatory exudation takes place between the surfaces of the pericardium, the pleura, or the peritoneum, the transudation of fluid into the cavity goes on until the pressure in the cavity becomes equal to that of the blood-vessels in the walls. Hamilton supposes that the granulations are formed by the dilatation of the blood-vessels and their extension upward toward the surface, where they are not opposed by the pressure of the tissue over them. In this way, by the longitudinal extension of the vessels, projecting loops would be formed. It is very probable that this lack of pressure of the surrounding parts has much to do with the dilatation of the blood-vessels which is found in a granulating surface and the slow movement of the blood in the vessels. The effect of removal of pressure is almost the same as would be produced by placing the entire hand in a vessel from which the air is exhausted. All of the blood-vessels would become more or less dilated, and there would be an increased difficulty for the passage of blood from the part, while the flow of blood to the part would be greatly accelerated and the transudation of fluid greatly increased. It is not probable that Hamilton is right in considering that the granulations on the surface of a cutaneous ulcer are due solely to the action of these influences on the normal blood-vessels, because there are no such groups of blood-vessels in the skin to which these granulations could conform. It is probable, however, that the absence of pressure has something to do with it.

The ulcer represents the best type of a chronic inflammation. The tissue is deprived of its protecting epidermis, and is subject to a continuous injury which will persist until the covering of epidermis is again restored. The tissue is not only subjected to the constant action of irritating substances, but also to drying. On the surface of the ulcer there is always a more or less superficial layer of necrosis. In the necrotic tissue and immediately below it there will be a variable number of pus-cells. These come not only from the normal blood-vessels of the part, but the emigration also takes place in the same way from the blood-vessels of the granulation tissue. The granulation tissue covers the entire base of the ulcer and extends to a variable depth in the tissue beneath. In places this extension into the deeper tissues is much more marked than in others. The granulation tissue is composed of small round cells closely packed together, with very little intercellular substance. On shaking the cells from a thin section little or no fibrilla-connective tissue is found between the cells, but the cells are held together by a mucoid substance. Blood-vessels are extremely numerous in these granulations. They are dilated, the blood flows in them with comparative slowness, and, in spite of the number of blood-vessels, it is

probable that less blood flows into the part, for the supply of the large vascular area of the granulation vessels is frequently only a small artery.

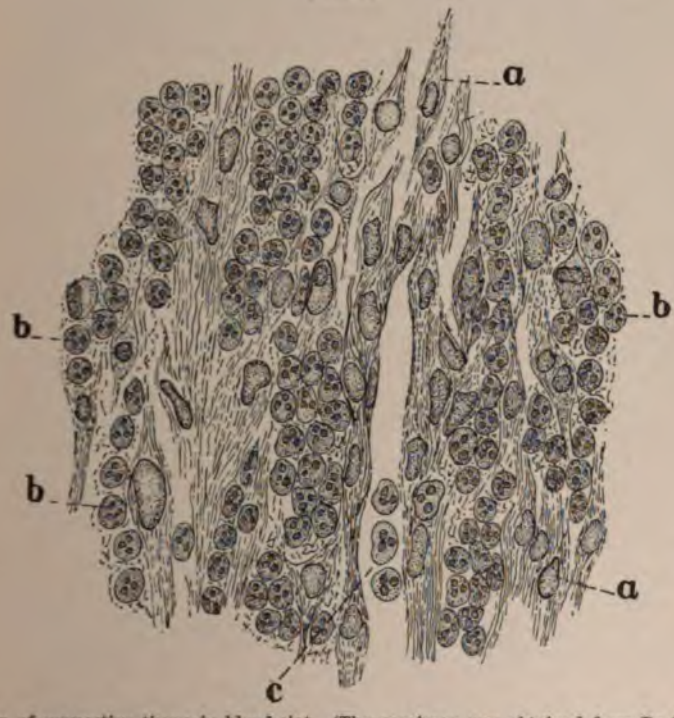
Repair of Inflammation.

When the cause of the inflammation is temporary the inflamed part returns very quickly to a normal condition. The vessels return to their normal calibre, the leucocytes cease to accumulate in the periphery and to emigrate, and the stagnation of the blood in the dilated vessels passes away. This may take place before any exudation has been formed. When exudation has taken place, this may not disappear, and the inflamed part cannot return to its normal condition because the presence of the exudation itself produces more or less injury to the tissue, affecting its nutrition in various ways and acting as a cause of inflammation. There is no difficulty in the removal of the fluid portion of the exudation. It is simply taken up and absorbed by the lymphatics of the part—a certain amount of it also by the veins. Even while the exudation is taking place there is increased absorption of the fluid, and an inflammatory œdema or a serous exudation soon disappears when the cause producing it has disappeared, and no new exudation takes place. Even the corpuscular elements of the exudation, and the fibrin as long as it is present in only slight amounts, may disappear. The colorless corpuscles can be removed in the same way as the fluids. They can enter directly into the lymphatics. The few red corpuscles in the exudation gradually lose their coloring material and are dissolved, and even the fibrin itself becomes changed into a granular emulsion which is taken up by the lymphatics. These simple processes of restoration are much more difficult when the mass of the exudation is very considerable, as in a large pleuritic exudation, an extensive pneumonia, or an extensive purulent inflammation. A large exudation may even oppose mechanical difficulties in the way of restoration of the integrity of the tissues. The absorption of these large exudations makes great demands on the functions of the lymphatics, especially in individuals in whom the force of the blood- and lymph-circulation has been weakened by inflammation. In any case the restoration must take place very slowly, and it is better to shorten the process of absorption whenever it is possible by artificial removal of the exudation. The blood-vessels may be compressed by the exudation, and the active circulation of blood in them necessary for absorption may be prevented. When an exudation is solid, being composed principally of leucocytes and fibrin, it must become in a measure liquefied before absorption can take place. In acute croupous pneumonia the exudation in the air-cells in consequence of fatty degeneration becomes converted into an emulsion, which can then be absorbed by the lymphatics and blood-vessels of the lung or can pass into the bronchi and be so removed. It is evident that the richer the exudation is in solid elements, the slower it will be absorbed, and this holds especially for exudations composed of pus-cells. In this the reason for artificial removal is still more forcible, because not only is the absorption of such an exudation more difficult, but as long as the exudation continues, containing as it does the bacteria which produce it, it acts as a further cause for inflammation.

When not removed the exudation may become changed into a yellowish-white, more or less dry mass of about the consistency of cheese. This is spoken of as the caseation of the exudation. It takes place preferably in those exudations due to definite causes, as in tuberculosis and syphilis, but it is not exclusively confined to these. Lime-salts may be deposited in this dry necrotic tissue, and it can be converted into a solid or gritty calcareous mass which must always remain in the tissue. It acts here as a foreign body, and, as other foreign bodies, it will continue to excite inflammation around it.

When the exudation disappears by simple absorption by the blood-vessels of the part, it is spoken of as resolution. In many cases the normal circulation of a part will not be sufficient to effect the removal of the exudation, and new tissue and new blood-vessels must be formed before the exudation can be removed. This is spoken of as the organization of the exudation: it is seen best on serous surfaces. When there

FIG. 8.



Formation of connective tissue in blood-clot. (The specimen was obtained from Dr. Halstead.) The clot first becomes infiltrated with leucocytes, and formation of tissue takes place, proceeding from the deeper tissue: *a*, young connective-tissue corpuscles; *b*, leucocytes; *c*, newly-formed blood-vessel.

is on the surface of the pleura a fibrinous exudation which reaches any considerable extent, it becomes organized. Beneath the exudation there is a regenerative new formation of tissue which takes place from the normal tissues. In this a tissue similar to the granulation tissue at the base of the ulcer is formed. New blood-vessels are developed in this,

which project upward into the fibrin. The formation of granulation tissue continues along these blood-vessels, and finally a young connective tissue is formed, the exudation disappearing as this takes its place (Fig. 8). In cases of inflammation of serous surfaces the same cause which produces the inflammation on one surface will act in producing an inflammation on the surface which it touches. When organization takes place a direct union by means of young connective tissue is formed between the two surfaces, and produces adhesions which may give more or less trouble in after life. The adhesions which are so frequently found between the visceral and parietal pleural surfaces are due to a preceding inflammation, which may have been of such a slight character as to have given rise to no symptoms and not to have been recognized during life. The exudation may in every place undergo organization; even in acute croupous pneumonia the exudation within the air-cells of the lung may in certain cases undergo organization in the same manner as the exudation on a serous surface, and there will always remain in the alveoli of the lung the newly-formed connective tissue. In inflammation which takes place in the parenchyma of organs the exudation may be in part removed in the same way, and a new tissue be formed which will not completely disappear. A certain amount of this new formation of tissue takes place in nearly all inflammations, and its presence may serve to indicate a preceding inflammation even when the exudation has disappeared.

In the repair of inflammation, in the restoration of the tissues to their normal integrity, not only must the exudation be removed, but the injury of the tissue which has been the cause of the inflammation in the first place must be repaired. In any inflammation there is always a destruction of tissue, and the tissue destroyed must be replaced by a new formation of tissue. This begins early, and may be seen while the inflammation is advancing. The new formation of tissue may be better studied in slight injuries of the cornea than elsewhere, and here the two processes, the vascular phenomena with the formation of the exudation and the new production of tissue, can be considered separately. When the loss of tissue is very slight, and when the action of the injury which caused it subsides at once, inflammatory phenomena with exudation and emigration do not necessarily take place. In the ordinary physiological processes of life, and in all tissues, there is constantly taking place a loss of material which is supplied without any inflammatory phenomena. The power of the tissue to supply a loss is greater than is ordinarily called for, just as in the circulation there is a reserved force in the power of the heart which can meet all ordinary conditions called for, and even extraordinary conditions, by an increased muscular action. In all the tissues of the body there is a greater power of repair than is ordinarily called for. But in the tissues, as in the circulation, this reserve force has its limit. The destruction of any considerable amount of tissue is always followed by inflammation. Even when the cause which produces the injury subsides at once, still the injured tissue itself will act as a sufficient cause. When a cornea is touched with the end of a thread saturated with sulphate of zinc, a very limited injury will be produced. This is followed by a new formation of cells in the territory immediately around the injury, to take the place of the cells

which have been destroyed. This new formation of cells begins forty-eight hours after the injury, and the same phenomena of cell-division take place that we find in cell-division anywhere. The nuclei of the cells divide by karyokinesis. Long processes are formed which extend up into the necrotic tissue, and the nuclei from the old cells travel up into these. In many cases there seems to be a difference in the regeneration of tissue, depending upon the degree of destruction. In the minor degrees of injury, where only the cells themselves are destroyed, there is simply a new formation of cells having the same character as the old, without any intermediate stages. In one point the pathological regeneration of tissue differs materially from the physiological. It is frequently not confined to a simple restoration of the tissue lost, but the amount produced widely exceeds this. In inflammation of the skin there is often an excessive epithelial growth, and scars may be produced from the connective-tissue regeneration which at first project beyond the level of the skin and appear as red elevations. In the inflammatory regeneration of bone more callus is produced than is necessary for the supply of the portions of bone which have been lost. The power of regeneration is different not only in the different tissues of the body, but also in different animals. The higher the organization and the greater the differentiation of tissue, the less is the power of regeneration, which is greater the younger the animal and the nearer it comes to an embryonic condition. In some of the lower animals, as the crustacea, an entire part may be removed, and it may be completely re-formed. In the frog the power of regeneration is much more marked in the tadpole than in the adult. When the tail of the tadpole is removed an entire new production of tissue will take place. The different tissues also show different powers of regeneration after loss. The more completely differentiated the tissue and the farther it is removed from an embryonic condition, the less is the power of regeneration. In some tissues it is probable that there is no new formation of cells, and only the portions of the cells which have been used up by the physiological processes will be restored. After injury in the central nervous system there is no new formation of nerve-cells. The same thing is true to a more limited extent in the striated muscles. Any loss in these tissues is supplied by a growth of connective-tissue elements. In certain of the glandular organs the power of regeneration is greatly limited.

The new formation of connective tissue in inflammation does not always take the form of a pure regeneration. In the place of the normal connective tissue a somewhat different tissue is formed, which is designated as cicatricial tissue. This cicatricial tissue differs from the normal connective tissue in the paucity of its cells and blood-vessels and in the density of its intercellular substance (Fig. 7). The character of the intercellular substance seems to be similar in general to white fibrous tissue, but its exact character has never been fully made out. The fibrillæ are more firmly interwoven together, and cannot be separated so easily as they can in white fibrous tissue. In some inflammations, especially in the more chronic, the new formation of connective tissue may so greatly exceed the necessary amount to supply the defect, and form so prominent a part of the inflammatory process, that inflammations of this character have received a different name and are known as

productive inflammations. The excessive amount of connective tissue which is formed may often exert a deleterious influence on the future life and the functions of the inflamed part.

In order that any new formation of tissue may take place new blood-vessels are necessary. The old blood-vessels of the part where the new tissue is to be formed have been destroyed to a great extent, and multiplication of cells will not take place except under the best conditions of nutrition. If regeneration to any extent takes place in non-vascular parts, these become vascular. In any extensive injury of the cornea new blood-vessels grow into the tissue from the sclera in a comparatively short time. In man ulceration of the cornea is always followed by a vascularization of the portion of the cornea between the ulcer and the sclera. These new blood-vessels are formed from the old. The formation takes place by direct outgrowth from the old vessels. In this formation both the endothelium of the vessels and the connective-tissue cells in the neighborhood of the vessels take part. The process is the same as in the new formation of blood-vessels in the embryo. It can be well studied in the regeneration of tissue which takes place after cutting off the end of a tadpole's tail. The first thing which seems to take place is an enlargement of the endothelial cells of the vessels. These become large, filled with protoplasm, and long projections extend into the neighboring tissue. The nucleus of the cells divides, and nuclei pass up into the projection in very much the same way as in the regeneration of the cells of the cornea. The connective-tissue cells in the vicinity enlarge, and arrange themselves either alongside of the projection from the endothelium or as a continuation of this. In this way pointed processes of some length are formed. These meet with similar processes from the same vessel or from neighboring vessels, and in this way loops are formed which are at first solid. These solid processes are gradually hollowed out and become continuous with the lumen of the vessel. In some cases the lumen of the vessel gradually follows the formation of the sprout. In other cases loops are formed before the communication with the lumen of the vessel takes place. In this new formation of blood-vessels there must be a process somewhat similar to chemotaxis. In the cornea the blood-vessels are always formed from that portion of the sclera which is nearest the ulcer, and they show no tendency at all to extend anywhere but into the cornea. In the formation of the loops there must be also a mutual attraction for the cells, because the meeting of the pointed process from the same or from neighboring vessels, and the resulting formation of loops, cannot be regarded as a matter of chance. This new formation of vessels always proceeds from the capillaries, and the newly-formed vessels are always of this character. They function as the old vessels. When the inflammation continues emigration takes place from them as readily as, or more readily than, from the old vessels. They are more easily dilated, and when dilated the dilatation frequently persists for some time. Later, these vessels may become differentiated into both arteries and veins, but the manner in which this differentiation is produced has not been fully made out. Other modes of new formation of the vessels have been described. According to some authors, the cells in the inflamed part, the cells of the tissue, may collect together in rows and may become

changed into endothelial cells, and a communication be established between the old vessel and the newly-formed; or large cells of the tissue may become hollowed out and in this way new cells are formed.

FIG. 9.

Section through a portion of a suture which had remained in the tissue eleven months. The suture first becomes infiltrated with leucocytes, and the formation of connective tissue takes place as in Fig. 8. The section represents only a fragment of the suture: *a*, *a*, silk fibrillæ surrounded by dense connective tissue; *b*, *b*, giant-cells enclosing fibrillæ.

Stricker believes that not only are new vessels formed from the cells in this way, but that there may be a new formation of red corpuscles in these vascular cells in the same way as in the embryo. The essential cause of the new formation of blood-vessels and the influence which leads to it are obscure. We know only, in general, that they are formed in accordance with the law of nutrition—that where more blood is required for a part it will be given, either by a dilatation of the old vessels or, if this be not sufficient, by a new formation of vessels.

There has been considerable controversy with regard to the participation of the leucocytes in the new formation of tissue. Cohnheim believed that not only were all the cells found in an inflamed part leucocytes, but that any new formation of tissue takes place from leucocytes. He was led to this belief by a number of experiments. He showed that there could be a new formation of tissue in parts in which all the living cells were destroyed by boiling and which were afterward placed in the peritoneal cavity of animals. The tissues became filled with

leucocytes which wandered into them, and, as a newly-formed connective tissue with blood-vessels was afterward found in the tissue, he believed that this new formation must take place from leucocytes. Some experiments which Ziegler made on this subject seemed to be at first conclusive. He enclosed two thin plates of glass with a capillary space between them in the subcutaneous tissue or in the peritoneum of an animal, and found that a thin lamella of connective tissue was formed between the plates (Fig. 9). The first thing seen in such conditions is a filling up of the spaces between the plates with leucocytes and fibrin. Afterward large cells with a round nucleus and a large amount of protoplasm appeared, and from these large cells the formation of connective tissue takes place, either by a differentiation of the body of the cell into fibrous tissue or by a sort of secretion from the cell. The exact method in which this formation takes place has not been fully made out. Ziegler supposed that these large cells were produced directly from the leucocytes, but a repetition of his work by other observers has shown that they, like the leucocytes, wandered into the glass cell from without. In any case the new formation of tissue seems to take place from the large protoplasmic epithelioid cells (Fig. 8). The leucocytes probably take a part in the process, but only a passive one. Many of these large cells are phagocytic in character, and it is probable that the leucocytes play a distinct part in furnishing them nutrition, being taken up and devoured by these large connective-tissue cells.

Sometimes there is in this way new formation of cells from the old, which simply supplies the tissue which has been lost. In this new formation of cells all of the tissues can take part. It is probable that the cells most actively concerned in it are the cells of the small blood-vessels. In other cases there is not an immediate formation of cells from the cells of the old tissue, but there are intermediate steps. The new tissue is not formed directly from the old, but there is a formation of granulation tissue first. In the cornea, for instance, if the loss of substance is extremely small, it may be supplied by a simple new formation of cells; if larger, there will be a preceding formation of granulation tissue. Some of the granulation cells will afterward differentiate themselves into tissue-forming cells. The tissue which is formed in this way from the granulation tissue is never so perfect as that formed directly. It always approaches the character of cicatricial tissue. The process of regeneration of tissue can also be studied on the ulcer, and in the ulcer we can also study the local conditions which may interfere with this regeneration. In the ulcer the regeneration of tissue must take place in two directions. There is not only a new formation of necessary tissue from the connective tissue, but a new formation of epithelium must also take place. Until the surface is covered over with epithelium it must be constantly subjected to various traumatic influences which will keep up the inflammation. If the ulcer is small and the local conditions favorable, the epithelium will grow in from the edges, cover over the surface, and the inflammation will subside. This new formation of epithelium takes place solely from the surrounding epithelium. It has been supposed by many that a new formation of epithelium may take place from the granulating surface of the ulcer. The proof of this was supposed to be shown in the fact that the growth

of epithelium does not always proceed evenly from the edges, but small islands of epithelium are sometimes formed in the middle of the ulcer, and from these a growth extends upward to the edges. These small islands which are formed in the centre of an ulcer do not represent a new formation of epithelium from the edges of the ulcer, but are the remains of epithelial tissues, such as sweat-glands or the sebaceous glands of the skin, which were not entirely destroyed by the injury which produced the ulcer. An ulcer never heals by a simple process of tissue-formation, such as is seen in the cornea, but there is always a formation of granulation tissue, and from this the regeneration proceeds, leading to the production of cicatricial tissue. The amount of cicatricial tissue varies with the extent and duration of the ulcer. It is exceedingly dense, firm, and contains few blood-vessels. It may extend into the surrounding tissues for a considerable distance beyond the actual seat of the ulcer. In the most common seat of ulceration, the anterior surface of the lower leg and ankle, there are numerous local conditions which interfere with the process of healing. In the first place, the ulceration is constantly repeated at the same spot. The tissue is not normal, it has not the normal vascular supply, and it reacts to injuries more easily. Not only is there this abnormal tissue with weak vascularization, but the ulcers usually arise in persons who have a local passive congestion. In the process of healing the new formation of blood-vessels does not so readily take place. As we have seen, in spite of the apparent vascularization of the tissue of the ulcer, it is really poorer in blood-vessels. Frequently, healing will not take place until the dense cicatricial tissue resulting from a series of old ulcers is removed in toto, or until incisions be made through it so as to allow vascularization to take place from the deeper and more healthy tissues beneath it.

The Effect of Inflammation on the Body as a Whole.

The objection was early made to the theory of inflammation of Cohnheim that all of the cells found in the inflamed part could not come from the blood, because there were not enough cells in the blood to produce these. In an acute fibrinous pneumonia one entire lung and a portion of the other may be so filled up with the inflammatory exudation as to resemble a solid mass and to sink in water. The consolidation of the lung is due in large part to an accumulation of leucocytes, and in a case of advanced pneumonia the number of leucocytes in the lung could not be estimated by numbers, but by pounds. The same thing is true in the large purulent exudation which we find in empyema or in peritonitis. There are at no time enough leucocytes in the blood to form such masses even if all of them could be taken up. It was supposed also that after the leucocytes had emigrated from the vessels they multiplied, and that many of them could be newly formed from those which at first emigrated. In speaking of this Cohnheim says that in general we can form little idea of the number of leucocytes in the blood from microscopic observation, because large numbers of leucocytes break up and disappear the moment the blood is taken on the slide for examination. He also suggests that there may be a new formation of leucocytes in the blood, and an increase in their number due to this. He

called attention to the enlargement of the lymphatic glands and spleen frequently seen in acute inflammation, and supposes that this may in some way stand in relation to the number of leucocytes found in the exudation. Cohnheim, however, made no estimate of the supposed increased number of leucocytes in the blood. As early as 1842, Gulliver called attention to the similarity between the pus-cells and the leucocytes, and thought that in inflammation the white corpuscles of the blood were increased; and he instances a case in which, in a stallion which had a large abscess, the white corpuscles of the blood were almost as numerous as the red. Virchow also, in his study of the blood in leucæmia, recognized the fact that in most acute inflammations, especially if they were at all extensive, the white corpuscles of the blood increased in number. He supposes that this is due to the fact that the lymph-glands and other blood-forming organs undergo a stimulation which excites them to an increased activity. We know now that in any inflammation, and especially in an infectious inflammation characterized by extensive exudation and emigration, the white corpuscles are increased. It is only recently, when the study of the corpuscular elements of the blood has received great attention, that the extent and importance of this leucocytosis have been recognized. The leucocytosis keeps almost an exact pace with the fever and the extent of the exudation. In croupous pneumonia we have the greatest extent of leucocytosis, and the number of leucocytes in the blood may be double or treble that of normal. The leucocytes which are found in increased number are exclusively of the polynuclear variety. The fact that in inflammations uncomplicated with hyperplasia of the lymphatic glands there is no increase in the mononuclear leucocytes speaks against the emigration of these and their taking part in the exudation. The mononuclear leucocytes are increased in typhoid fever and in other processes connected with a lymphatic hyperplasia. The recognition of a polynuclear leucocytosis in the blood is frequently of great importance in determining the character and extent of inflammation. We find other changes in the blood in addition to the leucocytosis, but they probably depend in large measure upon this. If the inflammation is sufficiently extensive and lasts long enough to interfere with the general nutrition of the body, a diminution in the number of red corpuscles may take place. In acute inflammations, especially when connected with an extensive leucocytosis, there is an increase in the fibrin of the blood. This has long been known, and was formerly used as a diagnostic means for recognizing the extent and character of an inflammation. Although the fibrin is increased in the blood in inflammation, it coagulates more slowly. This slow coagulation of the blood allows the red corpuscles to sink from the surface of the blood before coagulation takes place. As a result of this, on the surface of the clot there is a layer of coagulation which has a buffy or straw color. This is known as the buffy coat of the blood, and in the old days of bloodletting a great deal of importance was attached to it. Fever is a frequent accompaniment of inflammation.

II. FEVER.

FEVER can well be considered in connection with inflammation, for it is an almost constant accompaniment of it, and the effect on the general organism of a local inflammation is shown first of all in the production of fever. In fever the normal temperature of the body is increased. Usually this increased temperature is accompanied by other abnormal conditions, but these are not necessary to the condition. Observations on normal individuals show that the temperature of the body, in spite of variation in the surrounding temperature and in spite of all sorts of changes in the external conditions of life, has a medium value of 37.2° to 37.4° C. The absolute variations in the course of the day may be from 1° to 2.5° C. The body is able to maintain such a temperature, far above that of the surrounding medium, only by the production of heat by means of chemical processes taking place in the tissues. The production of heat is offset by a discharge of heat, which takes place by means of the skin, the lungs, and the various excreta of the body. Ordinarily, the production of heat and the discharge of heat are so evenly balanced that the temperature of the body remains the same in all conditions.

THE PRODUCTION OF HEAT.

The various chemical processes which take place in the body are accompanied by the production of heat. At every muscular contraction, in all the processes of glandular secretion, heat is produced. Of all the tissues of the body, the muscles, not only from their bulk, forming as they do a large part of the whole frame, but also from the character of their metabolism, must be regarded as the chief source of heat. Not only is heat produced in the contractions of the muscles, but during their quiescent period metabolic changes are taking place in them by which heat is produced. Next in importance to the muscles are the various secreting glands. The secreting elements of the glands in the periods of secretion, and probably in the quiescent period, are in a state of metabolic activity which must give rise to heat. In the case of the salivary gland the temperature of the saliva secreted during stimulation of the chorda tympani is 1° to 1.5° higher than that of the blood in the carotid artery. The blood in the hepatic vein is the warmest in the body. In the dog a temperature of 40.73° has been observed in the hepatic vein, while that of the vena cava was 38.35° and that of the right heart 37.7°. The brain, too, may be regarded as a source of heat, since its temperature is higher than that of the arterial blood with which it is supplied. The other tissues of the body also serve as sources of heat, but the part they play is insignificant as compared with the muscles and glands.

The increase of temperature of the body in fever may be due to either of two conditions: There may be increased production of heat, the discharge being the same or even increased, or, the production being the same, the discharge of heat may be reduced. One of the best known of the theories of fever was that advocated by Traube. According to his views, there was no increased production of heat, but the increased temperature was due to a decrease in the discharge of heat. The discharge of heat he supposed to be least in the earlier period of

fever and increased in the defervescence. A great deal of work has been done to determine whether there is increase of heat in fever, and its degree. Various methods have been used to determine this. The heat being the result of chemical changes in the body, it was sought to determine if these chemical changes were more active in fever. It is known that most fever patients lose weight and that there is increased consumption of tissue. The urea is increased, and for a long time it was believed that the increased excretion of urea afforded satisfactory evidence of increased oxidation and increased production of heat. Of late years investigations have been made upon the consumption of oxygen and the production of carbonic acid in fever, and it is found that there is an increase in the amount of oxygen consumed and in the carbonic acid given off. In the beginning of fever, when the temperature is constantly rising, both of these processes are most active; during the stage of defervescence the consumption of oxygen may fall below the normal. It has been claimed that the increased oxidation was not the cause of the fever, but simply resulted from the increased temperature of the body. Although it is true that there is an increase of oxidation in increased temperature, the elevation of the temperature 1° C. would only increase the oxidation 3.3 per cent., while in fever the oxidation may be increased 13–15 per cent. Although it has been generally accepted that in fever there is increased oxidation of tissues and increased production of heat, this alone would not be sufficient to explain the high temperature. The increase in heat-production in fever is far less than would take place in an individual making active muscular movements in a cold environment. In health the increased heat-production is met by a corresponding discharge of heat, so that it has no effect on the body temperature. The loss of heat in fever has been investigated by direct calorimetry. The discharge of heat is least during the initial stage of fever, and increases during the stage of defervescence. During the hot stage the discharge of heat exceeds the normal, but usually, on account of the dryness of the skin, is not so great as might be inferred from placing the hand on the surface. In the febrile chill not only is the discharge of heat by the contraction of the vessels of the skin reduced to a minimum, but heat-production is excited to the utmost. As the result of the work of most investigators it may be said that in fever both heat-production and heat-discharge are increased.

Recently, Rosenthal, who has investigated this question by means of a specially constructed air-calorimeter, using animals in whom fever was produced by the injection of various substances into the circulation, has returned to the view of Traube. He finds that in the initial stage of fever and in the stage of gradual increase of temperature the discharge of heat is diminished and there is no increased production of heat. When the fever has lasted a considerable time there is a return to the normal discharge of heat. The diminution in the discharge of heat he thinks is due to sudden changes in the circulation of the skin brought about by vasomotor influences. In the stage of defervescence the discharge of heat is greatly increased, and about corresponds to the decrease in the temperature.

If the regulatory mechanism were normal, the discharge of heat in fever would be increased in proportion to the increased production and the

temperature would be unaltered. The regulating mechanism, although profoundly disturbed, is not paralyzed in fever. External cold in fever to some extent stimulates the heat-production, but not nearly to the same extent as in health. A person in fever is not able to maintain his temperature under the influence of heat and cold to the same extent as a person in health. It is not merely, as some have supposed, that the regulatory mechanism is set for a higher degree of heat, but that it is disturbed. In both health and fever the regulatory mechanism is under the control of nervous influence. This acts through the vasomotor nerves presiding over the superficial parts of the body, and by producing variations in the calibre of the cutaneous vessels controls in great measure the discharge of heat. The perspiration which plays so great a part in the discharge of heat by evaporation is also under the influence of the nervous system. Heat-regulation is effected not only by means of variations in heat-discharge, but heat-production is also under the influence of the nervous system. In a cold atmosphere more heat is produced, and in a warm less heat, provided the external temperature is not so high or so low as to make it impossible to preserve the body temperature. To regulate the temperature simply by the discharge of heat would be like regulating the temperature of a room by opening the doors and windows and paying no attention to the furnace. There is every reason to believe that nervous impulses control chemical changes which result in the production of heat independently of visible alterations of the tissues, so that heat-production is in considerable part under the control of the nervous system. The nerves controlling the production of heat are known as thermic nerves, and they are controlled by centres in the brain. The chief of these centres is in the nucleus caudatus, and if this centre is stimulated by puncture with a needle or by electrical stimulation, fever, often reaching several degrees above the normal, will result. A number of cases have been collected in which fever resulted in man from injuries involving these centres in the brain. It is very probable that fever may be the result of the stimulation of these centres in the brain by pyrogenic substances in the blood. Opposed to this is the hæmic theory, which assumes that the increased temperature is due to the direct action on the tissues of pyrogenic substances contained in the blood. After puncture or stimulation of the caudate nucleus of animals they present all the phenomena of fever. There is increased heat-production, with increased consumption of oxygen, and the heat-regulation is also interfered with.

Liebermeister regarded all the phenomena of fever, the changes in the pulse, respiration, etc., as due simply to the effect of the increased temperature. He urged that the weakness of the heart, which is undoubtedly one of the most serious dangers in fever, was due to the increased temperature, which caused parenchymatous and fatty degeneration of the cardiac muscle. According to his views, the one great indication in treatment was to lower the temperature of the body. Of late there has been a reaction against these views of Liebermeister, which reaction has in part been brought about by the fact that antipyretic drugs may reduce the temperature, but may not affect the other phenomena of fever. Some authors have gone to the extent of not only denying that there is danger in temperatures which do not exceed a very high point,

but of stating that the elevation of temperature in itself may be a beneficent provision of nature in warding off the effects of disease. It is obvious that the effects of high temperature cannot be studied in the fevers of man nor in the artificial fevers produced by the injection of various substances into the blood. The effects of the temperature must be separated from the effects produced on the tissues by the agents which cause the increase in temperature. The effects of temperature alone have been studied by subjecting animals to a high temperature. Some of the earlier experiments have seemed to bear out Liebermeister's view of fever. It was found that animals whose temperatures were artificially raised to 40.5° or 41.7° C. showed evidences of illness. All experimenters agree that a mammalian animal dies when its temperature is raised to 44° or 45° C. Death is preceded by convulsions, and rigor mortis develops almost immediately after death. Death in these cases has been attributed to heart-paralysis due to heat-rigor, but it is known that heat-rigor does not take place at such temperatures. In all of the cases in which death took place after keeping the animal for some time at a temperature of 40.5°–41° fatty degeneration of the heart was found.

The most complete set of experiments on the influence of high temperature alone was made by Welch at the Johns Hopkins Hospital. In all the previous experiments the animals were kept in small, dark, badly-ventilated boxes, and the influence of the high temperature was assisted by the bad surroundings of the animals. In Welch's experiments the animals were kept in a large box partially closed at the top by a blanket. The box was surrounded, except at the top, by a layer of water. The animals were supplied with an abundance of green food and water, which they took greedily. He succeeded in keeping two large black rabbits for two weeks with an average rectal temperature in one of 41.4° C. and in the other 41.8°. The animals lost weight while in the box in spite of their abundant food, but otherwise seemed perfectly well. He found considerable differences in different individuals in their capacity of withstanding high temperatures, and thinks, in general, that black rabbits are more resistant than white. In all cases, after keeping the animals for some time, extensive fatty degeneration of the heart, liver, and kidneys was found. He is not inclined to attach so much clinical importance to the fatty degeneration of the heart as some have done. In a series of experiments which he made on animals in whom fatty degeneration of the heart had been produced by heat he found that the blood-pressure was kept at the usual height, and the heart reacted to nervous stimulation in the usual way. In one case he observed the contraction under the microscope of some fibres of heart-muscle in which the fatty degeneration was so advanced that no striation could be seen. He thinks from this that the effect of fever on blood-pressure is not due to increased temperature alone, but to other factors. Animals which had been rendered anæmic by bleeding were more affected by increased temperature than normal animals. Animals with an artificially increased temperature had their capacity for temperature regulation disturbed, so that they were more susceptible to the effects of heat and cold than normal animals. The various fevers differ materially in the effects produced. In relapsing fever temperatures can be withstood which in typhoid fever or pneumonia would be fatal.

In fever the frequency of respiration is increased. This has been attributed to the direct effect of the heated blood upon the respiratory centres in the medulla. The experiments of Goldstein made in Fick's laboratory are generally quoted as completely settling this point. He surrounded the carotid arteries with tubes in which hot water circulated, and found the respirations increased. In order to produce any appreciable increase of temperature in the blood rapidly flowing through the artery, by exposing the vessels for a space of a few cm. to warmer surroundings, the tube around the vessel would have to be very hot, and a high temperature in the surrounding tube would have so injured the vessel that coagulation would take place. Sihler repeated the experiments of Goldstein, and concluded that the increase in the respiration was not due to heating the blood, but to stimulation of the peripheral nerves. Welch found that in the hot box animals with a surrounding temperature of 32°–35° C. often preserve their normal temperature, though the respirations are increased. When animals with fever are taken out of the box the respiration often decreases before the temperature falls. The increased frequency of the heart's action is due to the direct action of the heated blood on the cardiac muscle. This has been shown by Martin on the isolated mammalian heart. When the heart is fed with blood of gradually increased temperature, the rapidity of the heart up to a certain degree keeps pace with the increased temperature. The heart continues to beat when supplied with blood of a much higher temperature than is found in fever. The nervous phenomena of fever cannot be attributed to the effect of high temperature on the nervous centres, for the effect of fever on the nervous centres may be entirely absent in relapsing fever and in the aseptic wound-fever.

Fever may be due to an infinite number of causes. In general the fevers are divided into the symptomatic and the essential, though no sharp line can be drawn between the two. In the symptomatic fevers it is assumed that there are local lesions somewhere in the body from which substances are produced which when absorbed cause fever. At one time there was a theory that in an inflammatory focus there was a direct production of heat, and fever was the result of this local heat-formation. In a strict sense there are no essential fevers, and the distinction is a purely artificial one. Fever is generally due to the presence in the blood of substances which are capable of causing it, and to which the name pyrogenic has been given. A great deal of work has been done of late in the investigation of these substances. Most of the normal ferments of the body, particularly fibrin-ferment, may give rise to fever when injected into the blood. Of great interest in this connection is the aseptic fever which was described by Volkmann. It follows injuries to the tissue in which there is no possible infection. Nothing shows more clearly the line which should be drawn between the high temperature and the other phenomena of fever. This aseptic fever has no prognostic importance. In a case of subcutaneous fracture, with extravasation of blood into the tissues, temperatures of 40° C. or over may be seen without any other phenomena of fever save slightly increased pulse and respiration.

Absorption of perfectly aseptic products of tissue-necrosis will give

rise to fever. Gangolphe and Commont have shown that the injection of the germ-free tissue-juice from gangrenous tissues is in a high degree pyrogenic. They also produced necrosis in the testicle by means of a ligature, and found that the fluid of the necrotic tissue produced fever. The power of fibrin-ferment in producing fever is well known. Any substance which will give rise to it acts as a pyrogenic agent. Thus water injected into the blood will give rise to fever. It has been claimed that most of the substances which produce fever act by producing coagulation in the capillaries and small blood-vessels, and so giving rise to fibrin-ferment. Hildenbrandt found that after the injection of various ferments into the blood there was extensive thrombosis of the small vessels in the liver, intestine, lungs, and kidney. The presence of fibrin-ferment cannot be regarded as the sole cause of the fever, for the highest temperatures are not found in the diseases in which the greatest quantity of ferment is found in the blood, and fever may be present in cases in which this ferment is entirely absent.

It is questionable whether fever may be the result of irritation of the peripheral nerves. The cases usually cited as examples of this are the fever of children during teething and the fever which sometimes follows the introduction of a catheter. It does not seem reasonable that all cases of catheterization fever should be ascribed to the introduction of bacteria or to injury of the urethra. There are numbers of cases in which the careful introduction of an aseptic catheter has been followed by a chill and fever lasting a short time. The chill may follow so shortly after the introduction of the catheter that time is not given for the increase of bacteria should any have been brought with it, and it is not probable that the pyrogenic substances produced by bacteria elsewhere are on the catheter. Nor is time given for the development of sufficient inflammation to cause fever even if an injury was produced by the catheter. In many cases a temporary increased temperature is the only phenomenon. The case is different when fever follows the introduction of a catheter into an inflamed urethra or bladder. In regard to the question of production of fever from peripheral irritation, a strong argument against it is that it is only in certain parts of the body that such irritation is followed by fever. No irritation of the skin in general which is not followed by inflammation will produce fever. In the inflamed bladder or urethra the pyrogenic material is already present, and sufficient injury may be produced to cause its absorption. Most of the chemical products of bacteria are pyrogenic. These may be absorbed into the circulation from a local lesion of some sort, or they may be absorbed from the alimentary canal without any local lesions being present. There is no doubt that abnormal processes of fermentation in the alimentary canal may produce chemical substances which when absorbed may give rise to increased temperature and the other phenomena of fever.

It is easy to see why inflammation should be so constantly accompanied by fever. In the inflammatory exudation, whether of an aseptic or septic character, substances are present which, when absorbed, are pyrogenic. Not only is there in every case fibrin-ferment, but the products of simple necrosis of tissue are pyrogenic. If the inflammation be due to bacteria, there are added to the pyrogenic substances of the exudation the chemical substances produced by the bacteria. If there is no

accumulation of the exudation in the tissues and no absorption, fever does not take place. In wounds treated by the open method, where the products of the inflammation are not absorbed, there is no fever unless the inflammation extends into the surrounding tissues and allows absorption from these. The dependence of fever upon absorption is shown in its prompt decline when an inflammatory exudation, especially if it be purulent, is evacuated. There is good evidence that the increased temperature in fever is not in itself a source of danger unless it reaches a very high degree. There is also some evidence that the increase of temperature may not be an evil, but a beneficent agent. The most dangerous cases of pneumonia are frequently not those in which the temperature is highest. Serottin has found that when sterilized cultures of typhoid bacilli are injected into the blood of rabbits, recovery is more apt to take place when the temperature is elevated. Welch has observed the same thing. Cases of typhoid fever of especial malignity have been reported in which the temperature was subnormal throughout. It is no longer the custom to judge the severity of wound-fever by the degree of the temperature elevation. Many surgeons consider the condition of the circulation and other things of far more prognostic value than the evidences given by the thermometer. Dochman found that when cats were given curare the poisonous influence of the drug was far less when the animals were given a temperature of 40° C. by keeping them in the warm chamber than when they were kept in ordinary temperatures. While there were apparently no symptoms produced in the heated animals, poisoning rapidly developed when they were exposed to ordinary temperatures. He further calls attention to the fact that all infectious diseases accompanied by fever have a tendency to recover, while the afebrile infectious diseases, such as leprosy and rabies, have no tendency to recover.

From all we have seen of inflammation it seems evident that its phenomena are essentially conservative in their action on the organism, and it cannot be assumed that so marked a phenomena as the fever should have the opposite tendency.[1]

III. THROMBOSIS AND EMBOLISM.

Thrombosis.

Thrombosis is the coagulation of the blood in the vessels during life. When blood is taken from the vessels during life, after standing some time it undergoes coagulation, changing from a fluid to a solid form, and the vessel containing it can be inverted without spilling the contents.

We owe the most of our knowledge of the process of coagulation and the factors concerned in it to the work of Alex. Schmidt and his pupils. Schmidt was able to separate from the blood two substances, each with definite chemical properties, to one of which he gave the name of paraglobulin and to the other the name of fibrinogen. The fibrin of the blood does not exist pre-formed in the blood, but is due to

[1] In these remarks on fever extensive use has been made of the Cartwright Lectures on fever by Prof. W. H. Welch.

the union of these two substances, the union being brought about by the presence of a third substance which has all the characters of a ferment, and which is called fibrin-ferment. This ferment is destroyed or rendered inoperative at the death-point of protoplasm and of the other ferment-substances of the body; that is, at about 58° C. If the blood be heated to 58° C. before any coagulation has taken place, the power of undergoing coagulation is lost. The ferment appears to be principally contained in the white corpuscles and is set free by their disintegration. Other tissues of the body may contain this substance, or substances which are analogous to it and which act in the same way. A proteid substance may be obtained from the thymus gland which when injected into the circulation produces extensive coagulation in all the vessels and leads to the death of the animal. The disintegration of other tissues of the body also produces fibrin-ferment. In necrosis, substances are produced which cause coagulation in the blood-serum which comes in contact with the necrotic tissue.

A new theory of coagulation has been advanced by Arthur and Pages. These observers found that if a certain proportion of oxalate of potash be added to freshly-drawn blood, it loses its power of coagulation. They attribute the action of the oxalate to the precipitation from the blood of the soluble lime-salts which it contains. If a solution of chloride of lime be added to the blood containing the oxalate, coagulation will take place. No matter how long the oxalated blood may be kept, it will remain fluid, and coagulation will take place as soon as the lime-salts are driven from their connection with the oxalate and again set free in the fluid. The fibrin-ferment only acts on the fibrinogen, converting it into fibrin when lime is present. In coagulation the fibrinogen undergoes a chemical change by which it is converted into fibrin, the fibrin being a union of lime-salts and albumin.

The coagulation of the blood in the vessels during life is prevented by some action exerted on the blood by the living endothelium of the blood-vessels. The blood contains the necessary element for coagulation, and a certain amount of fibrin-ferment must be constantly produced by the disintegration of leucocytes and other cells, which to some extent is always going on. In inflammatory exudations and in the necrosis of the tissues fibrin-ferment is certainly present, and being soluble it must enter into the circulation. If a large vein of an animal be carefully ligated and removed from the body while filled with blood, coagulation of the blood contained in this receptacle does not take place for a long time, and when it does the clot is always thinner than when formed under ordinary circumstances. The serous tissues act in the same way in preventing coagulation. If small vessels are included between double ligatures, care being taken to prevent any injury to the vessel by the ligature, the blood in the vessels will not coagulate. Stagnation of the blood in the absence of other factors will not produce coagulation in the vessels, but it will favor it. If the wall of the blood-vessel is injured in any way, thrombi will be formed on the injured surface. It is not known to what this action of the living endothelium in preventing coagulation of the blood is due. It is not due to the smoothness of the surface alone, for Virchow has shown that thrombi will form around globules of quicksilver when they are brought into the

circulation. It is probable that the prevention of coagulation is a property of the living endothelial cells. The endothelial cells do not simply provide a physical lining to the vessels, but have as definite properties as gland-cells, and they may produce substances which oppose the action of the fibrin-ferment.

Coagulation of the blood takes place in the vessels a few hours after death. Certain conditions favor or oppose the post-mortem coagulation. An excess of carbonic acid in the blood retards the coagulation, and in death after suffocation the blood is usually found fluid. The blood is fluid, or clots feebly, after death from certain poisons and from a number of infectious diseases, especially those due to the absorption of chemical bacterial poisons. The blood is firmly clotted after death from pneumonia, in which disease the fibrin-ferment in the blood is increased. The clot found in the vessels may resemble the clot formed outside of the body, or in certain places, notably in the heart, clots are formed which are colorless and transparent, and resemble the clot obtained by whipping the blood and gathering the fibrin. Clots of this sort are not strictly post-mortem. For their formation a certain amount of motion in the blood is necessary, and it is probable that they form in the last minutes of life, especially under circumstances in which the power of coagulation is increased, as in croupous pneumonia.

Three principal varieties of thrombi may be distinguished, and there are various intermediate stages. The white thrombus is of firm consistency and has a grayish, and sometimes a yellowish-white, appearance. On microscopic examination it is principally composed of white corpuscles and fibrin. Many of the white corpuscles are apparently normal and their nuclei stain clearly; others show every stage of disintegration. The fibrin appears either in the form of very minute filaments, forming a meshwork and enclosing the leucocytes in its meshes, or the filaments may be large and coarse. At times the thrombus has a hyaline, more transparent appearance, and this is due to the presence in it of large masses of hyaline material which stain in the same way as fibrin, and which probably result from a hyaline metamorphosis of the fibrin. In many cases the fibrin is arranged in definite layers which may be stripped off. This is especially the case in the large thrombi formed in aneurisms. The whole space of the aneurism is frequently filled with lamellæ of fibrin. Along with the leucocytes and fibrin a certain number of red corpuscles are generally found, and a quantity of granular material, which may result from disintegration of the fibrin or white corpuscles, or may have another origin.

The red thrombus is less firm than the white. The red color is due to a greater number of red corpuscles, or pigment resulting from their disintegration, entangled in the meshes of the fibrin. The red thrombus shows various degrees of color, depending upon the amount of blood-pigment in it, and is formed more rapidly than the white.

In the mixed thrombus there is a combination of both forms. It frequently has an exquisitely lamellated structure, a red lamella following a white in regular order. This mixture of the two colors is due to an alternation of rapid and slow coagulation on the surface.

The consistency of the thrombus may differ in different parts. We can frequently distinguish a firmer portion of the thrombus to which

the remainder is loosely attached. The firm portion is the true thrombus, which is due to the local cause, and the other is simply a coagulum formed on this. The soft red coagulum may extend from the thrombus a considerable distance in the blood-current, and is called the secondary or continued thrombus. When a vessel is completely occluded the thrombus extends up to the next branch entering or given off from the thrombosed vessel.

True thrombi may be distinguished from post-mortem coagula in a number of ways. Thrombi are more consistent than post-mortem clots; they are more adherent to the walls of the vessels. The adhesion is due to several causes. If the thrombus be sufficiently old and if organization has taken place in it, there is a definite tissue-union between the thrombus and the vessel-wall. Even if there is not formation of tissue extending from the wall of the vessel into the thrombus, there is frequently a formation of fibrin in the wall of the vessel which unites with the fibrin of the thrombus.

The thrombus may occupy various relations to the lumen of the vessel. It may fill up the entire vessel or occupy only a small portion of the wall, allowing the blood-current to flow past it. As a rule, thrombi are formed by coagulation over a small area of the wall of the vessel, and then successive coagula are formed on the first. In the heart these successive coagula may be formed until a large mass projecting like a polypus into one of the cavities of the heart is produced.

Another variety of thrombus is due to aggregations of the blood-plates. There is still much contention about these blood-plates and the part which they play in coagulation and thrombus-formation. It is held, on the one hand, that they are essential constituents of the blood, and on the other that they result from the disintegration of white corpuscles. Eberth and Schimmelbusch, in studying the experimental formation of thrombi, found that the first appearance of the white thrombus was due to a collection of these blood-plates. They form with the greatest rapidity just at the point where the vessel is injured. They call the thrombus so formed the blood-plate thrombus. Welch has also found that thrombi which at first are entirely composed of blood-plates can be produced experimentally by slight injuries of the wall of a blood-vessel, and it hardly seems probable that all the leucocytes which had collected at such a place could have broken down. Weigert does not consider these aggregations of blood-plates as true thrombi. He considers the thrombus a true coagulation of the blood, and not an aggregation of some of its constituents. A considerable amount of granular material which is found in the thrombus may be composed of these blood-plates. Zahn studied the formation of thrombi in the veins of the mesentery of a curarized frog directly under the microscope. He found that when a crystal of salt was placed in contact with the vein the first change noticed was a collection of leucocytes at the point. Finally, the entire lumen of the vessel was occluded by the leucocytes. In the course of some hours the thrombus underwent important changes. The white corpuscles lost their form and regular contours, and became changed into a more or less finely granular mass, and then fibrin-filaments appeared.

Both local and general conditions favor the formation of thrombi.

The local conditions favoring their formation are stagnation of the blood and changes or injuries in the lining membranes of the vessels. Experimentally, it seems to be shown that when the blood is enclosed in a vessel between double ligatures coagulation will not take place if the vessels be ligated so carefully that all injury to the wall is prevented. Even if we suppose that a lesion of the endothelium is necessary for coagulation, such a lesion may be produced by stagnation of the blood. The endothelium of the blood-vessels is nourished by the blood, and not only the blood, but its constant renewal, is necessary, and a loss of function of the endothelium due to lack of nutrition would suffice to produce coagulation. As a rule, the smaller the blood-vessel in which stagnation takes place, the less likelihood is there of coagulation. The larger the area of blood relatively to its mass which comes in contact with the endothelium, the less readily will coagulation take place. In a small vessel degeneration of the endothelium would not be so likely to take place, because it could more readily be nourished by imbibition from the surrounding tissues. The thrombi produced by stagnation of the blood are formed first in the pockets behind the valves, where the stagnation is most complete. Thrombi may form around foreign bodies, but there is little opportunity given for this mode of formation in man.

Virchow first called attention to the part which alterations in the walls of the blood-vessels play in the formation of thrombi, and regarded the coagulation as the result of altered molecular attraction between the wall of the vessel and the blood. Ulceration, inflammation, necrosis, and various other pathological conditions in the neighborhood of blood-vessels may so affect their walls as to lead to thrombosis. Frequently the coagulation which takes place under such circumstances is essentially a conservative process, and the hemorrhage which would otherwise follow the extension of the ulceration into a large vessel is avoided. Dilatations of vessels favor the formation of thrombi. The thrombus forms the more easily the more sharply circumscribed and the more partial the dilatations are. In such conditions, of which the best type is given in aneurism, the thrombosis is further assisted by calcification and various degenerations of the lining wall of the aneurism.

Various conditions of the system favor the formation of thrombi. They are frequently found in weak marantic individuals, particularly when they have had long-continued suppuration. In such individuals thrombi are frequently found in the pockets behind the valves of the veins, in the sinuses of the dura mater, and in the auricular appendages and between the muscular trabeculæ of the heart. Virchow considered the essential factor in the production of such thrombi the weakness of the heart and circulation. Even in such conditions the thrombosis may be favored by local degenerations of the endothelium. The nutrition of the vessels will suffer in consequence of the diminution in the general nutritive power of the blood and the diminution in its rapidity of flow. These conditions will be felt most where local conditions favoring stagnation are present.

There may be certain chemical alterations in the blood which increase its coagulability. The injection into the blood of the extracts of certain glands, especially of the thymus gland, increases its coagulability. Extracts of hæmoglobin, especially the hæmoglobin derived from

a different animal, has the same effect. There were numerous examples of this when the blood of different animals was used for transfusion. Under such circumstances death frequently occurred shortly after the transfusion, and at the autopsy extensive thrombosis was found. In certain cases there may be such extensive thrombosis in the vessels that the existence of substances in the blood which materially increase its power of coagulation must be assumed. These are cases in which in a very short time, and apparently without any lesions in the walls of the vessels, there is extensive formation of thrombi. It is possible that substances may be formed in certain organs of the body, and may have a local influence in assisting thrombosis. There may be extensive thrombosis, especially in the very smallest veins and capillaries, which occurs in the course of certain infectious diseases. The thrombi formed under these circumstances are different from the ordinary thrombi, being composed almost entirely of hyaline material. Such thrombi are frequently found in vessels of the kidney and the lungs.

The thrombus when once formed undergoes various changes. It contracts and becomes firmer and harder. Softening frequently takes place, especially in large thrombi formed in the heart and large vessels. The thrombus becomes converted into a soft pulpy mass of an opaque granular appearance closely resembling pus. The softening most frequently takes place in the centre of the thrombus. In the softened material of the thrombus there is a quantity of fatty granular material which is derived from the breaking down of both the cells and the fibrin. The fluid in the centre is frequently surrounded by a dense outside wall. The fluid results both from the absorption of fluid from the blood and the contraction of the thrombus. This softening may take place until the thrombus resembles a cyst filled with fluid. The thrombus may become organized and converted into a mass of connective tissue. The manner in which the organization of the thrombus takes place has been the subject of a great deal of dispute among pathologists, and the study of the process has led to a material increase of our knowledge about this and the formation of pathological connective tissue in general. It was at first supposed that the connective tissue in the thrombus was formed by a direct conversion of the constituents of the thrombus into connective tissue. It is now known that the organization of the thrombus is due to a growth of connective tissue into it from the wall of the blood-vessel. It is not probable that the white corpuscles in the thrombus itself take any part at all in the organization. In the first stages of the organization of the thrombus it becomes filled with leucocytes which are derived from the wall of the blood-vessels. In some cases it seems probable that there may be an invasion of the thrombus by leucocytes which are derived from the blood itself. After the leucocytes, and along with them, large epithelioid cells appear which are derived from the walls of the vessels. These cells are accompanied by a new formation of blood-vessels proceeding from the adjacent blood-vessels of the tissue, and a new formation of connective tissue takes place from the large epithelioid cells. The leucocytes appear to prepare the way for the after-formation of tissue, and, as in the connective-tissue formation in inflammation, it is probable that they to some extent furnish food for the growing cells. The thrombus in the course

of organization becomes filled with large dilated blood-vessels that frequently communicate with one another. Under favorable circumstances communications may be formed between the blood-vessels of the thrombus and the lumen of the vessel, and in this way the continuity of the lumen of the vessel may be again accomplished. The red thrombus in the course of time becomes decolorized and converted into a yellowish or yellowish-brown material. The thrombus may become calcified, and, in consequence of this, becomes converted into a hard, calcareous mass. The so-called vein-stones, or phleboliths, are due to calcification of thrombi. The calcification is due to the deposition of lime-salts in the thrombus. All of these changes in the thrombus are relatively favorable. Other changes are not so favorable. There may be an actual purulent softening of the thrombus. When there is purulent inflammation in the tissues around the thrombosed vessel the suppuration may extend to the blood-vessel and into the thrombus. Not only may the pus-cells wander from the vasa vasorum and enter the blood-vessel and thrombus, but the pyogenic bacteria may also be carried by these. Under such circumstances no organization of the thrombus takes place, and it becomes converted into a soft friable mass.

Embolism.

Although the thrombi may produce both local and general effects on the circulation, these are not the chief dangers which result from them. In many cases the thrombus does not entirely obstruct the wall of the vessel, and the blood circulates in the vessel beyond the thrombus. Even when the thrombus completely occludes the vessel, it extends up to the next collateral branch, and frequently beyond this, so that a portion extends into a vessel where the circulation is still taking place. The thrombi, further, are more frequently found in the venous side of the circulation than in the arterial. The chief danger from the thrombi is that portions may be washed off, carried into the circulating blood, and finally occlude arteries. The thrombi being more frequent in the venous system, the particles which are washed off from them occlude the vessels of the lungs. When thrombi are formed in the left side of the heart and in the arterial system generally, they will be carried into some other part of the circulation. The particles of the thrombus which may be broken off and enter into the blood-stream vary in size. The largest pieces come from the thrombi formed in aneurisms, from the heart-cavities, and from the large veins. These portions of the thrombus which are carried by the blood-current to another portion of the body are called *emboli*. Where they will lodge depends upon the position of the thrombus. If they come from the veins, they will enter into the pulmonary arteries. Those from the arterial side—that is, from the left heart, the systemic arteries, and the lung-veins—are carried into the systemic arterial system, and those from branches of the portal vein into the branches of the portal vein within the liver. These emboli will be carried along by the blood-stream, and finally stop where the calibre of the blood-vessels is smaller than the diameter of the emboli. Virchow, and especially Recklinghausen, have called attention to the fact that there may be a transportation of thrombi in a direction contrary to

the blood-stream. It is difficult to see how this takes place. It may be assisted by gravity, and it can only take place in parts where the circulation is exceedingly feeble and the blood-pressure in the veins very low. Large emboli can occlude the chief branches of the pulmonary arteries, or on the arterial side may occlude large arteries, such as the renal or iliac, or even the descending aorta. The smallest emboli may enter into the capillaries, and where the capillaries are relatively wide, as in the lungs, they may pass through these, and afterward plug up the narrower capillaries of the systemic circulation. It is evident that solid particles whose diameter is smaller than the capillaries can pass unhindered through all parts of the circulation. The emboli are apt to be found in places where the lumen of the vessel undergoes a sudden diminution in size, especially where large branches are given off.

It is not uncommon to find emboli entering into each branch of an artery at the place of its bifurcation. Such emboli are spoken of as riding emboli, situated as they are at the place of bifurcation, as in a saddle, with one leg in each division of the artery. The emboli almost always produce total occlusion of the vessel where they are found. They are carried with some force into the vessel, and being comparatively soft they will be pressed into it until they totally occlude it. The emboli may undergo the same changes as thrombi. They can become softened or they may organize.

There may be special varieties of emboli which are not due to thrombi, but which are due to substances accidentally introduced into the vessels. Under certain conditions either air or a fluid which will not readily pass through the capillaries, such as oil, may be introduced into the circulation. A large number of cases have been reported of death in human beings attributed to the entrance of air into the veins. This accident has generally happened in surgical cases where operations have been done about the neck, shoulders, and skull. Further, death has occurred in cases in which air has entered the sinuses of the puerperal uterus, generally in cases of criminal abortion in which air has been injected into the uterine cavity. In some of these cases death has been instantaneous, and in these there seems to be no reason to doubt that it has been due to the entrance of air into the circulation and the stoppage of large areas of the vascular territory of the lungs. A considerable amount of doubt, however, has been thrown on such cases by the result of experiment. It has been shown that the amount of air which is required to kill a dog if the air is directly injected into the vessels is much greater than could possibly enter the vessels in a surgical operation. If the air is injected slowly, enormous amounts can be injected without producing anything more than slight disturbances of the respiration and the action of the heart. In the cases in which death has been attributed to the entrance of air into the veins a large quantity of air or gas is found in the blood-vessels after death. Welch has shown that this is frequently due to the growth of an aërobic gas-producing bacillus in the blood. There is no doubt that a number of the cases which have been reported of death from air-embolism, in which death has taken place some time after the supposed entrance of air, have been due to infection with this bacillus, but there is equally no doubt that there have been cases of sudden death due to the entrance of not

very large quantities of air into the circulation. The air is especially apt to enter into the veins if there is an inspiration at the same moment when a large vein, such as the jugular, is opened. When a large amount of air enters the heart at one time, death may quickly take place with evidences of suffocation. This is due to collection of air in the heart. The air is not forced out of the heart at each contraction of the ventricle, but is simply compressed. When a small amount of air enters slowly it will enter into the circulation, and may produce temporary occlusion of a number of the capillaries in the lungs. Unless the vascular territory so occluded is very large there will be little inconvenience, because the air will gradually be forced through the capillaries by subsequent contraction of the heart, and in a short while most of it will become absorbed.

The presence of fat-emboli in the vessels of the lung has attracted considerable attention, but the importance of these emboli has been very greatly over-estimated. The fat of the body is in a fluid condition during life, the fat-cell representing a drop of fluid oil enclosed in a vesicle. When a number of these vesicles are broken, as in extensive crushing injuries, and the veins are ruptured at the same time, a certain amount of this fluid fat can enter into the circulation. It is especially apt to do this in injuries of the bones where there is not only a large amount of fat in the marrow, but where the veins are large and do not collapse. The fat entering the circulation in this way is nearly all stopped in the capillaries of the lungs, and may be found there at autopsies. It was at one time supposed that the shock after severe surgical injuries could be in large part explained by fat-embolism. It is rare, however, that the fat is present in sufficient amount to produce any serious results by occlusion of the capillaries. The collateral circulation in the capillaries is so abundant that no result can take place from the occlusion of a few. It is only when all of the capillaries of a very large area are occluded that any results will follow.

The General and Local Effects of Thrombi and Emboli.

An occluding thrombus in any portion of the venous system will lead to congestion and increased venous pressure in the vein behind the thrombus. The severity of the changes produced will depend upon the local conditions of the circulation in the part and the size of the vessel. If a large vein be occluded, it is evident that the consequences will be more serious than if the vein be a small one. Local conditions of the circulation affecting the results produced by a thrombus are due to the abundance or absence of collaterals. When there are two veins leading from a part with an abundant anastomosis between their branches, the occlusion of one of them will have no effect. The rapidity with which the thrombus is formed will also influence the result. If the renal vein be ligated, intense passive congestion of the kidney with hemorrhage and necrosis results. Complete occlusion of the renal vein by a thrombus is sometimes seen without producing any results. The thrombus is formed slowly, and time is given for the dilatation of the vessels of the collateral venous circulation, so that by the time the occlusion is complete these vessels are sufficiently dilated to carry off all the

blood from the kidney. The same thing is true of the portal vein. When this is ligated death results from the enormous distention of its branches. When it is slowly occluded by means of thrombus-formation the few collateral branches dilate sufficiently to carry off the main portion of the blood, although the collateral circulation is rarely sufficient to prevent ascites and passive congestion. Sudden occlusion of the femoral vein in the neighborhood of Poupart's ligament is usually fatal. Intense congestion, œdema, and gangrene of the entire leg develop. When the occlusion takes place gradually by the slow formation of a thrombus or by pressure of a tumor, no unfavorable conditions other than œdema to a greater or less degree may develop.

The local effects of an embolus will depend to a certain degree upon the physical character of the embolus. Virchow found that when hard substances, especially those with irregular walls, were introduced into the circulation, they produced intense inflammation, frequently with rupture of the vessel at the point where they were arrested. Wherever an embolus lodges and whatever its character, it will always produce changes in the wall of the vessel in contact with it. The endothelium will become necrotic, and the necrosis may extend some distance into the surrounding tissue. Other local changes may be produced which do not depend upon the physical characters of the embolus, but upon its biological characters. The embolus may consist of living tissue, which may grow where it lodges. Particles of tumor are frequently carried by the circulation from a primary focus to a distant organ, and develop, forming secondary tumors where they lodge. Not only particles of living tissue, but living organisms, may be contained in the embolus, and these will produce the same lesions as in the place from which they were derived. This is especially seen in the emboli which come from the purulent softening of a thrombus. In this way a secondary abscess may be formed around an embolus.

The occlusion of an artery will produce effects in the tissue supplied by it. Here the effects produced will depend upon the presence or absence of collateral branches going to the same tissue. In certain parts of the body definite areas of tissue are supplied by definite arteries without anastomoses. Such terminal arteries are found in the kidneys, heart, and other organs. The effect produced will also depend upon the size of the artery. The collateral circulation may suffice for a small area, but not for a large one. There may be produced by the occlusion of an artery two conditions which are apparently widely different. If the artery be a terminal one, the tissue supplied by it becomes necrotic. The form of necrosis produced is that described by Weigert as coagulation-necrosis, in which there is necrosis of the cells with coagulation. The anæmic part has a whitish, opaque character, and is generally triangular in shape, the apex of the triangle being formed by the occluded artery. Or a hemorrhagic infarction may be produced. In some cases hemorrhage takes place into the previous anæmic territory. The source of the blood in this case has been a matter of dispute. Cohnheim supposed that it was due to a backward flow from the veins, but this can be shown to be erroneous, because the infarction takes place when the veins are tied at the same time with the artery. The blood may have various sources. It is impossible by arterial occlusion to shut

off all blood from a part. There are always anastomoses with the capillaries of a neighboring part, and if the anæmic area be very small the capillary anastomoses will be sufficient to preserve the life of the tissues. The first effect of arterial occlusion must be to lower the pressure in the circulation distal to the occlusion. The pressure will be lower in all the vessels of the part, and the blood will flow into it from all the adjacent vessels. The blood-vessels become distended and diapedesis of red corpuscles takes place. If the amount of blood entering the vessels of the part is not sufficient to provide for a regular circulation, all of the tissue becomes necrotic. The diapedesis is generally supposed to be due to nutritive changes in the walls of the vessels, but it may be the result of changes which have taken place in the character of the blood. A combination is frequently seen between hemorrhagic and anæmic infarctions. The centre of the infarction may be white and anæmic and be surrounded by a hemorrhagic zone. In this case sufficient blood does not enter the vessels to penetrate to the centre, or necrosis with coagulation may take place before it has sufficient time to do so. Various conditions of the body may influence the effects produced by an embolism. If the circulation is feeble and the general state of nutrition poor, the effect will be more disastrous. Embolism of the pulmonary arteries, unless the vessel be of considerable size, may not produce any effects. In the ordinary conditions of the pulmonary circulation there is sufficient capillary anastomosis, assisted by the anastomoses of the bronchial artery, to preserve the life of the tissue. In any embarrassment of the pulmonary circulation, especially in chronic passive congestion, infarction always results.

That a part is able to retain its vitality after the occlusion of a large artery supplying it with blood is due to the development of the collateral circulation. After the ligation of the femoral artery below the point where the profunda is given off, the leg not only retains its vitality, but in a short time it will be able to perform all its functions as well as before. It must receive the same quantity of blood, and it cannot do this unless the other arteries dilate. No adequate explanation has been given for the dilatation which takes place. It cannot be explained on physical grounds, because tying the artery does not produce any increase of pressure in the branches given off above the ligature. The dilatation of the collaterals in this case is more complicated. Every tissue receives just the amount of blood which it needs for its nutrition and function, but no more. The varying amount is provided for by varying degrees of contraction of the muscular walls of the arteries. Where a small artery has to supply a large part with blood, it not only dilates to the fullest extent, but the calibre of the vessel actually grows larger. The dilatation is the result of the close relation between the calibre of the arteries and the needs of the tissue—a relation probably directly under nervous control.

IV. HYPERTROPHY AND REGENERATION.

In hypertrophy there is an increase in the size of an organ or part of the body, with retention of the normal structure. In regeneration a loss of substance in an organ or part of the body is restored by a tissue similar to that which is lost or which contains the same constituents.

A tissue can enlarge either by an increased power of assimilation or growth, or by diminution of the consumption of the tissue. Such a condition is physiological during the entire period of growth. When a part is growing, more tissue is formed than is used up. The normal size of organs and the general conditions of growth depend upon causes which are inherent in the germ. In order that growth may take place an abundant nutrition is necessary, which is provided in the intra-uterine life by the mother and in extra-uterine life by alimentation. The growth of the individual tissues and organs is dependent also on the activity of the blood- and the lymph-circulation. An extremity of a child ceases to grow, or it may even diminish in size, when for any reason the blood-supply is diminished. If all the conditions of nutrition are favorable, and if there are no general disturbing influences acting on the tissues, such as abnormal temperature, for instance, the development and growth of every individual take place at a rate corresponding to the age. The influence of the nervous system for such growth as this is not absolutely necessary. Examples of this are given in the monstrosities in which children are born without either brain or spinal cord. In these cases the body may sometimes show a development even in excess of the normal. The cells apparently from the beginning have the power of excessive reproduction—that is, reproduction in excess of the material used up—for a certain length of time, which differs in different animals. This ceases in man at about the twenty-second year, and nothing can again excite it. This does not hold for certain tissues; as, for instance, for muscles, for glands, and for the epithelial tissues generally. In these the power of forming new substance does not cease with the end of the period of growth. Every muscular contraction and every secretion of a gland takes place at the expense of the substance of the muscle and the gland; and in order to supply this continual loss there must constantly be a new formation of contractile substance or of gland-cells. Even in the adult there may be an increase in the size of certain parts brought about by exercise and good alimentation. Arterial congestion, however, no matter how excessive, will not of itself produce an increased growth. Apparently the cells of the muscles and glands will only assimilate when they are stimulated, and congestion alone will not produce contraction in the muscle nor increased secretion in a gland. In other tissues assimilation and new formation apparently only depend upon conditions which govern the growth; that is, the inherent power of reproduction and the degree of congestion. In all of these tissues an excess of production may take place when they are subjected to constant hyperæmia. Cohnheim thinks that the growth of these tissues is due alone to the regulation of the blood-supply. He says that the bones and epidermis cease to grow at the end of the growth period, merely because if all the other organs of the body are supplied with blood in the proper measure, the quantity of blood which they receive will not be sufficient to excite growth.

The increase of size of organs due to increased functional activity with increased blood-supply is familiar to us in the muscles and in the glands. When more work is thrown on the heart in consequence of increased pressure which has to be overcome, or in consequence of lesions of the valves, that portion of the heart which is called upon to do

an increased amount of work becomes enlarged. An enlargement of the muscular walls of the bladder, which relatively can exceed that of the heart, takes place when, because of stricture of the urethra or enlarged prostate, it is forced to do a greater amount of work in expelling its contents. The same thing may be seen in the glands. When one kidney is destroyed, the other can undergo such an increase in size and weight that it will correspond to both kidneys and properly perform the functions of two. In other glands which are not necessary for the life of the individual, but only for the preservation of the species, as the testicles in man and the ovaries and mammary glands in the female, such a compensatory hypertrophy does not take place at all or only to a very limited degree. Hypertrophy only occurs when in consequence of the loss of one organ a greater amount of work is thrown upon another organ; and this will not be the case for the testicle or the ovary. Extirpation of a part of the thyroid gland will lead to an increased size of the part which remains; not only that, but other glandular structures which probably have the same function will also undergo an increase of size after extirpation of a part of the thyroid An increase in the functional activity of one portion of one lung in consequence of inactivity in other portions will simply produce a distention of the alveoli of the lung which may lead to atrophy instead of hypertrophy. In general, the younger the tissue the more readily will compensatory hypertrophy take place. In tissues which are constantly being used up a diminished consumption may also produce hypertrophy. For instance, in the epidermis and the nails there is constant consumption of the horny layer, and anything which interferes with this constant rubbing off may lead to pathological thickening. The removal of pressure from tissues can also lead to new formation of tissue. The inner surface of the skull can become thickened when the growth of the brain in childhood is inhibited. Frequently-repeated mechanical and chemical irritation of the tissue may lead to hypertrophy. Repeated irritation of the skin can lead to the production of callosities and corns. The continuous inhalation of dust can lead to development of connective tissue in the lungs, but this cannot be considered as hypertrophy in the true sense of the word. It is rather a reproduction of tissue to take the place of that which was lost, and the new tissue has not the same structure and function. The cause of hypertrophy in many cases is entirely unknown.

Formerly a sharp distinction was made between hypertrophy and hyperplasia. By hypertrophy, strictly speaking, we understand an increase in the size of an organ due to an increased size of its constituent elements, without any new formation. In hyperplasia there is a new formation of tissue. These terms can be used interchangeably, for in hypertrophy there is always hyperplasia. It cannot be always assumed that when an organ is increased in size there is at the same time increased functional capacity, because the hypertrophy may not concern all parts of the organ. When a gland is increased in size, this may be due to an increase in all of the elements of the gland, or only the connective tissue may be increased in amount. This imperfect new formation of tissue can reach such an extent that hypertrophy may take place in one tissue of the gland while the other part undergoes atrophy. In such cases it is generally the specific constituents of the tissue, the ganglion-cells, the

nerves, the gland-cells, etc., that are atrophied, while the connective tissue increases in amount. One of the most striking examples of this is seen in the pseudo-hypertrophy of the muscles. Although the muscles appear to be enormously increased in size, this is not due to an increase in the contractile substance. Hypertrophy may also take place in the period of embryonic development or during the period of extra-uterine growth without our being able to assign any cause whatever for the increased growth of the tissue.

The power of regeneration in tissues is always more or less limited. The more highly developed the tissue, the more its elements are differentiated for particular functions, the less complete is the regeneration. In the lower animals the power of regeneration exists to a very much greater extent than in man. Whole extremities of crabs and lobsters can be regenerated, and even in the lower vertebrates the same power exists. The younger the animal the greater the power of regeneration. In man the power of regeneration is limited. Whole pieces of tissue built up of complex elements, such as a finger or portion of the brain which is lost, do not regenerate. In adults the ganglion-cells of the nerve-centres have no power of regeneration. In the highly-developed glands the power of regeneration exists to some degree, but is limited. Single cells of the gland when lost are easily replaced by multiplication of surrounding cells, but when large areas are lost the structure of the gland is only imperfectly reproduced, and granulation and cicatricial tissue take the place of the lost substance. The surface epithelium, the epithelium of the glandular ducts, the connective tissue, and the nerve-fibres have the power of regeneration to a marked degree.

When a tissue whose elements correspond to the normal, but which does not perfectly agree with the type of the tissue in which it has developed, is produced in a part, such a new formation is called a heteroplasia. For instance, a cicatrix in the liver represents a heteroplasia, because, although it is composed of connective tissue and may contain typical glandular elements, its whole structure does not agree with the structure of the liver, although this also contains connective tissue and glandular elements. The connective-tissue hyperplasia which takes place in the course of inflammation may also be regarded as heteroplasia. There is also a condition known as heterochronia; that is, a tissue may be formed which represents a normal type at a certain period of development, but which no longer conforms to the normal type. Hypertrophy and regeneration are always associated with an increase in the number of the constituent elements. Increase in size of an organ may be brought about by a simple increase in the size of the single cells, but this does not play any part in pathology.

The division of the cells which leads to a new formation of tissue is characterized by peculiar processes which take place in the nucleus and protoplasm. Recent investigations have shown that both the body of the cell and the nucleus possess a complex structure. In both the protoplasm and in the nucleus a thread-like structure can be distinguished which encloses more or less numerous granules, some of which have a perfectly definite form. Sometimes these threads are so arranged as to form a reticulum or sponge-work in the tissue. In the nucleus a thread-like reticulum is formed, and the points where the threads join form the

granules. In various places the nodal points are larger and more marked. This same fibrilla structure is more condensed around the outside of the nucleus and forms here a sort of membrane. In the cell itself much the same structure can be recognized, but the granules and threads in the cell stain differently from those in the nucleus. The division of the cell is preceded by changes both in the protoplasm and in the nucleus. The chromatin of the nucleus becomes arranged in a different manner, and this change in the nucleus seems to be preceded by changes in a peculiar body in the cell-protoplasm, known as the centresome. This body apparently divides first, and the two granules become arranged on either side of the nucleus. An unstained, spindle-formed structure extends from this both into the cell and into the nucleus, and then the various changes in the nucleus take place. Division of the cell so brought about is known as the karyomitotic, or the indirect cell-division. It was at first supposed that this was the only way in which cell-division took place, but there is also a direct division of the nucleus. This form of cell-division is seen both in the leucocytes and in the lymphocytes.

The formation of new cells is the first stage in regeneration. The new cells provide the formative tissue from which the typical tissue of the part is developed. In the regeneration of tissues the different embryonic tissues only produce the same tissue. The epithelial cells can under no circumstances produce cartilage or bone, nor is a connective-tissue cell able to produce either the surface or the glandular epithelium. This law was formerly not so clearly known, and many authors believed that the most different tissues could be formed from connective tissue. In the formation of the epithelial tissues the cells become united to one another by intercellular substance, the structure conforming to the type of the normal tissue. In the formation of connective tissue the most prominent feature is the formation of intercellular substance from the cells, and the character of this intercellular substance gives the various connective tissues their peculiar properties. In order that hypertrophy or regeneration of the tissue may take place the cells must have the power of multiplication. Most of the cells of the body possess this power, but others seem to have apparently lost it. These are cells which in the course of development have undergone a marked differentiation. The more the protoplasm of the cell departs from the type of the embryonic cell by differentiation for specific purposes, the more does it lose its power of regeneration. The horny layers of the epidermis, the non-nucleated red blood-corpuscles, the ganglion-cells of the brain of an adult, all seem to have lost their power of multiplication. The more indifferent cells, such as the connective-tissue cells, those of the bone-marrow, of the spleen, of the lymph-glands, and certain of the epithelial cells, have retained this power to a marked degree.

The power of multiplication is one inherent in the cells themselves, and even when separated from their surroundings and placed in new localities they are still able to proliferate. On this power of growth depends the possibility of the successful transplantation of tissue; that is, the transference of a piece of tissue from one place into another part of the body. Pieces of the periosteum or of the bone-marrow have been placed in various parts of the body or in blood-vessels, and have

there grown and developed normal tissue. The experiments which John Hunter made in transplanting the spurs of young cocks into the comb, where they grew more actively than in their normal situation, are well known. The tissue most frequently used for transplantation is the skin, and this method may be used to make up even large losses of substance.

The great power of reproduction in embryonic tissues has been shown by experiments in the transplantation of tissue. The cartilage of an adult animal either does not grow at all or makes a very feeble growth when transplanted to new tissue. Portions of embryonic cartilage so transplanted lead to an excessive growth. Leopold and Zahn transplanted pieces of embryonic cartilage into the anterior chamber of the eye and obtained a considerable new formation of cartilage. The transplantation of tissue must be done in animals of the same species, because the blood-serum and tissue-juices of an animal of one species generally have a poisonous action on the cells of an animal of another species. The transplanted tissue must also have a certain amount of cohesion and firmness, otherwise the intercellular substance will be dissolved out and the tissue destroyed. It is probable also that the cells need contact with the adjoining cells—that they derive mutual support from each other in their efforts to live in strange surroundings. In general, the growth of the tissue transplanted is limited. This is especially the case with pieces of tissue which are implanted deeply in the body. Growth only goes on for a certain time; it then ceases, and the cells may disappear by absorption. As a rule, transplantation of the skin is not only the most useful, but is the most successful. The transplantation of skin can be made both on fresh and granulating wounds, especially on wounds which are covered with vascular, actively-growing granulations. Large thin pieces of skin which have been cut off with a sharp knife, and which consist of only the epidermis with the cut ends of the papillæ or only the upper portion of the corium, may be placed on fresh granulating wounds and kept moist. The adhesion of the tissue takes place by means of the lymph or blood. After about eight days the transplanted tissue becomes firmly united with the tissue beneath. Portions of the tissue may be kept for several hours in normal salt-solution before they are used for transplantation. The nutrition of the transplanted piece of tissue appears to take place first by means of the imbibition of nutrient material from the juices of the tissue. Later, a germinal tissue bearing blood-vessels grows up into the transplanted tissue. In some cases it appears to be evident that a direct connection is formed between the blood-vessels of the transplanted tissue and those of the old tissue. It is hardly possible to suppose that the transplantation of large parts—such as the entire finger, for instance—would be successful were this not the case. It would appear impossible for an entire finger to receive sufficient nutriment by means of imbibition to keep alive. Before new blood-vessels could grow from the base of the finger into the severed part necrosis would certainly take place, yet we know that portions of the finger, and even entire fingers, may be cut off and kept for some time, and then be successfully replaced. When the surface epithelium is transplanted the horny layer is cast off, and the adhering tissue at first consists only of the lower layer of germinal tissue, upon which a new horny layer is formed.

The process of pigmentation in the skin has been studied by means of the transplantation of epithelium. It has been found that when the skin of a white man is transplanted on a negro the transplanted skin soon becomes pigmented, and the pigmented skin of the negro loses its pigment when transplanted on a white man. This experiment shows clearly that the skin-pigment is not formed in the epithelium, but is derived from cells in the tissue beneath, which have the physiological power of forming pigment.

The question as to the cause of pathological new growth of tissue in regeneration and the conditions necessary for it to take place is quite obscure. One of the theories with regard to this, and which appears to be very plausible, is that the cells of the tissue have an inherent power of growth which is held in check by their relations to the surrounding tissues. When this relation is altered in any way, as when a loss of substance takes place, the cells in the vicinity, having the inhibitory influence of the surrounding tissues removed, proliferate actively. Other observers believe that the cells have a certain irritability, a power of action which may take the form of growth, and under the influence of certain conditions of irritation they may be excited to growth.

Among the influences which increase the capacity of proliferation of the cells, and which lead to a new formation of cells, increased nutrition brought about by hyperæmia has an important place. It is certain that this congestive hyperæmia makes possible an increase in the nutrition of the cells. It is probably necessary for cell-proliferation, but it is not probable that this alone leads to proliferation. The cells are not nourished, but they nourish themselves. In general, it is probable that proliferation of the tissue in regeneration should be regarded as a secondary process which in most cases depends upon a removal of the restrictions of growth. In various attempts which have been made to excite growth by chemical and mechanical irritation a lesion of the tissue, a trauma of some sort, is always produced. It may take the form of a direct loss of substance or of necrosis. The regenerative changes which take place in the epithelium are relatively simple. Division of cells takes place by means of karyokinesis, and may be easily studied. In epithelium composed of several layers cell-division appears to take place only in the cells of the deepest layers near the blood-vessels. These cells are always younger than the others, and their protoplasm has undergone no differentiation. The formation of keratin, representing a differentiation of the cells of the skin, only takes place after the cells have been produced a certain length of time and are removed a certain distance from the centre of growth.

In the regeneration of any tissue the new formation of cells does not seem to take place from any part of the tissue at random, but only from certain portions of the tissue. This was first studied by Flemming in the lymph-gland, and he found that in the gland there are certain centres of growth which he described as the "keimcentren." In the liver such places are seen in the periphery of the lobule, and in the skin in the lower layers of the epithelium. It is very probable that this is due to more favorable conditions of nutrition of the cells in these centres of growth, but it may be that in these places certain cells retain their embryonic power of growth. The newly-formed cells frequently have

not the same morphological and functional character as the old, and may approach the embryonic type. In the new formation of epithelium in the lungs which takes place in chronic inflammation accompanied with extensive loss of epithelium lining the alveoli, the newly-formed cells in the alveoli frequently have the character of columnar cells. On surfaces which are lined with ciliated epithelium the newly-formed cells do not acquire cilia for some time, and in the place of ciliated epithelium pavement epithelium may be formed. This is frequently seen in the healing of ulcers of the larynx and trachea. Small losses of substance in the surface epithelium are usually quickly replaced by growth of the epithelium in the neighborhood.

Loss of substance in the glandular epithelium is quickly replaced in case the structure of the gland is not altered. Thus in the kidney the loss of single cells in the epithelial tubules after inflammation accompanied by desquamation is quickly restored by regeneration proceeding from neighboring cells without any permanent lesion being produced. If, however, the structure of the tissue is destroyed and the relation with the surrounding tissues altered, complete regeneration is not apt to take place, and the site of the loss of substance is occupied by cicatricial tissue. In glands in which two sorts of epithelium are found—as the liver, for instance, in which we find both liver-cells and bile-ducts—in cases of loss of substance, regeneration takes place more readily and more extensively from the bile-ducts than from the liver-cells. The epithelium lining the bile-ducts is of the same character as that of the liver-cells, and represents a condition more nearly approaching the embryonic state. In some cases after loss of substance in glands a new formation of gland-tissue takes place in the same way as in the embryo. In the compensatory hypertrophy of one gland which follows the loss of a gland of similar structure and function there may be both an increase in the size and function of the epithelium of the remaining gland and also a new formation of tissue. This has been studied in the growth of one kidney which follows after removal of the other, but it is not yet fully understood. It is not certain whether there is a new formation of complex structures in the kidney, such as the glomeruli, or whether these simply increase in size and in functional capacity. If new glomeruli are formed, this could only take place by a general return of the tissues to the embryonic condition. New tubules must be formed, and at the end of these glomeruli must be produced in the same manner as in the embryo. In the growth of the kidney which takes place before the adult size of the organ is reached there does not seem to be any new formation of glomeruli, which simply undergo an increase of size. The younger the kidney, the smaller the glomeruli. In the epithelium lining the intestinal canal extensive processes of regeneration may take place. In the healing of large typhoid ulcers of the intestine, just as in the healing of ulcers of the skin, there is a new growth of epithelium which extends from the edges and covers over the loss of substance. In the newly-formed epithelium the simple glandular crypts are produced, but the more highly differentiated structures, such as the villi, are not. The newly-formed glands are not so numerous nor do they have the same typical structure as in the normal intestine.

Sometimes in the process of epithelial regeneration the new forma-

tion of tissue may be far in excess of that necessary to supply the defect. The epithelium in every part of the body, especially the surface epithelium, has an almost unlimited power of growth. If there is a definite change in the character of the connective tissue beneath it—if the normal connective tissue, for instance, is replaced by a tissue containing great numbers of cells with a small amount of loose intercellular substances—the epithelium grows downward into such a tissue. At the edges of ulcers of the skin this atypical growth of epithelium may take place to such an extent that the structure of a typical epithelial carcinoma may be produced. The growth of the epithelium only extends into the pathological connective tissue, and the normal tissues are not invaded by it. In cases of intestinal suture the epithelium of the crypts of Lieberkühn grows downward through the suture, and an extensive growth, resembling an adenoma and extending even to the peritoneum, may take place.

In all processes of regeneration new formation of blood-vessels plays an important part, because only by a new formation of blood-vessels can the excessive nutrition which is necessary for regeneration be brought about. New blood-vessels will be formed even in non-vascular parts, as in the cornea. The new formation of blood-vessels has been sufficiently considered in Inflammation.

The different members of the connective-tissue group show a marked difference in their respective powers of regeneration, which are most active in the periosteum, the bone-marrow, and the lymphoid tissue. The cartilage, on the other hand, is capable of only a slight power of regeneration. On the second day after fracture of bone the cells in the vicinity of the fracture enlarge and multiplication begins. In the physiological regeneration of tissue the newly-formed cells take the place of the old. It is simply a growth of the old tissue, without any intermediate steps and without any alterations of structure. When a large amount of young tissue is formed in a short time, the character of the old tissue is not immediately reproduced, but the growing cells and the blood-vessels form a germinal tissue which is usually known as granulation tissue. The extent to which this is produced varies in different cases, and depends upon the capacity of growth of the tissue on the one hand and the extent of the lesion on the other. After fracture of bones an excessive amount of this germinal tissue may be produced. The growing cells are larger and richer in protoplasm than the cells of the old tissue. They may have one or two nuclei, and sometimes cells with numerous nuclei, the so-called giant-cells, appear. All the cells may unite in the formation of the future tissue. When connective tissue develops from such cells they are known as fibroblasts or inoblasts.

The formative cells of cartilage and bone have received the name of chondroblasts or osteoblasts. The most varying forms of cells are seen in the forming connective tissue. The first step in the formation of the definite tissue is seen in the appearance of fine fibrillar bundles between the cells, or a homogeneous intercellular substance may be formed which afterward becomes differentiated into fibrillæ. The formative cells increase in size, and finally lie in small spaces in the tissue. In the development of hyaline cartilage a hyaline ground substance appears between the cells, and the chondroblasts assume a round form.

As the ground substance increases these cells become smaller, and finally lie in round spaces, the wall of which forms the capsule of the cartilage-cell.

The formation of new osseous tissue is a very complex process. In this a homogeneous or fibrinous substance forms between the cells, and afterward becomes infiltrated with lime-salts. The forming cells become smaller, and finally lie in small irregular cavities, and are designated as bone-cells. When there is an abundant formation of germinal tissue this direct change of the tissue into bone is limited. Within the germinal tissue an irregular meshwork of firmer tissue may appear, due to the formation of firm homogeneous tissue between the cells. This is at first not calcified, and is known as osteoid tissue. Afterward the intercellular substance becomes impregnated with lime-salts. The newly-formed osseous tissue is very extensive, being softer and looser in structure than the old bone, and the gradual conversion of this newly-formed tissue into a tissue similar to that of bone is quite a slow process. Mucous tissue is formed from the germinal tissue by the formation of homogeneous, gelatinous, intercellular substance which contains mucin. Mucous tissue frequently represents a transitory stage of growing connective tissue, and it may be afterward converted either into fat or into fibrillar connective tissue. Adipose tissue may develop in places which normally contain fat or it may form in any of the connective tissues. The regeneration of the blood is a process which is not well understood, in spite of the frequency with which it takes place. The blood is a very complex tissue, containing a number of elements of different origin. The formation of the round mononuclear cells of the blood takes place in the lymphatic glands, and these cells are simply taken into the blood from these glands. We know very little about the formation of the polynuclear leucocytes. This takes place in the bone-marrow and in the spleen, but the various steps connected with it are not known. There are cells in the blood which are regarded as progenitors of the polynuclear leucocytes, though the number is too small for us to regard them as the only progenitors of these cells. The new formation of red corpuscles is better understood. It is supposed that they are formed in the bone-marrow from certain cells which are called erythroblasts, by conversion of the protoplasm of the cells into the red corpuscle, the nucleus becoming extruded.

New formation of muscular tissue takes place only to a limited extent after loss of substance. The increase of size of the muscles in hypertrophy is principally due to increase in size of the muscular fibres. After injury or loss of substance in the muscle the muscle-nuclei become elongated and divide. The cells of the connective tissue and sarcolemma also show rapid proliferation. The substance of the muscle between the nuclei becomes broken up into larger and smaller masses, so that the muscle-cells lie in spaces between these fragments. The fragments are absorbed, and a new formation of muscular tissue takes place from the newly-formed cells. The process is quite a slow one, and is frequently not completed until two months after the injury. When the loss of substance is extensive there is never sufficient new formation to completely supply the defect, and the gap is occupied by connective tissue.

Regeneration of the cellular constituents of the central nervous system

does not take place in man, or in the mammalia generally, in post-embryonic life. When there is a small loss of substance in the central nervous system a formation of connective tissue takes place; if the loss is large, a cyst is formed. New formation of nerve-fibres of the peripheral nervous system is frequently seen. It takes place in all cases when nerve-fibres are cut across or in any way partially destroyed. Degeneration always takes place in the peripheral part of the nerve-fibre after section or injury of any sort. The central part, having a connection with the nerve-cell, preserves its vitality, and from this growth takes place. Regeneration begins in the central stump of a nerve a very few days after section, taking place by a growth of the axis-cylinder of the central end of the nerve. When the peripheral degenerated nerve is in contact with the central end, the growing fibres will extend along the old nerve to its muscular or sensory distribution. The presence of the old nerve gives the proper direction to the growing fibres. If the growing axis-cylinders do not reach the old nerve, they may extend for some distance in the connective tissues, but more usually they either undergo atrophy or take various directions into the surrounding tissues and are finally lost. Regenerative processes may also take place in the central ends of the nerves after amputation. The regenerative growth may be considerable, and large masses composed entirely of a convolution of rolled-up nerves may appear on the cut ends of the nerves. These are called "amputation neuromas," and frequently give rise to a great deal of pain.

V. DEATH; NECROSIS; ATROPHY; DEGENERATION.

THE tissues of the body are only capable of existing and preserving their function for a certain length of time. Their power of regeneration becomes less and less as age advances, and finally the regenerative processes are no longer able to keep pace with the rapidly-advancing processes of degeneration. Death from old age may be attributed to the gradual wearing out of the organs and the gradual loss of resistance which the diminution of the powers of regeneration entails upon them. Life ceases with the gradual destruction of the function of one organ after another. Destruction of the function of the heart, of the lungs, or of the nervous system produces death in a very short time. After destruction of the function of the intestinal canal, of the liver, or of the the kidneys the organism as a whole is just as certainly deprived of life, but some time may elapse before death takes place.

In contradistinction to this general death of the organism the local death of a part, or of single cells or groups of cells, is called necrosis. With the appearance of this local death or necrosis, affecting groups of cells or an entire organ, changes of structure take place. These changes of structure occur so gradually that it is impossible to determine the exact moment when the cells cease to live, and frequently in the early stage of necrosis neither the microscopic nor the macroscopic appearance is sufficient to tell us whether necrosis has taken place. The causes of necrosis of the tissue are various. The tissue may be destroyed by direct mechanical or chemical action. A finger can be crushed by

external violence; a portion of the skin may be destroyed by sulphuric acid; and germs may destroy tissue in which they develop. The thermic death-point of protoplasm lies between 54° and 60° C. If tissues are exposed to this degree of heat for a short time, necrosis is produced. Lowering the temperature does not seem to exert the same unfavorable influence. Even in mammals portions of the body may be completely frozen for a short time and afterward be restored to function. When the tissues do not receive the proper supply of blood their function and resistance may be impaired, and if the blood-supply be sufficiently reduced necrosis results. This form of necrosis is called anæmic necrosis. Examples of it are given in the various infarctions due to arterial occlusion.

The neuropathic necrosis is due to interference with, or inhibition of the function of, the trophic nerves. Regeneration of the tissue and nutrition generally are largely under the control of the nervous system. Regeneration does not take place so completely when the nervous supply of a part is destroyed. Samuel found that when the long feathers of the wings of pigeons are pulled out they are only incompletely regenerated when the nerve of the wing has been cut. The supposed trophic influence of the nerves, however, cannot be separated from the action of the vasomotor nerves which accompany them. As examples of necrosis due to interference with the functions of the trophic nerves the rapid and severe bed-sores which develop in the course of certain diseases, especially after injury of the spinal cord, are cited.

Any condition which in any way interferes with the circulation in a part, such as thrombosis, embolism, closure of vessels by continual tonic contraction, by lesions of the walls, by ligature, by pressure from without, inflammation, hemorrhage, etc., can produce necrosis. In certain tissues temporary cessation of the circulation lasting but a short while may produce necrosis. The various tissues have varying powers of resistance to disturbances of the circulation. In general, the more highly organized the tissue is, the more rapidly does it succumb. The epithelial cells of the kidney will undergo necrosis when the circulation is shut off for only one or two hours. The ganglion-cells of the central nervous system are also very sensitive. Other tissues can withstand the shutting off of the circulation for a very much longer time. The skin, the bone, and the connective tissues generally may live for ten or twelve hours after the circulation has been cut off. Cases have been known in which small portions of the body, such as the fingers, have united perfectly when replaced six hours after removal. If the circulation in the tissue is imperfect or its nutrition in any way interfered with, as in general marasmus or hydræmia, it undergoes necrosis much more easily than a perfectly normal tissue. Necrosis takes place much more readily in old people and in those in whom the action of the heart is imperfect. In a part subject to chronic passive congestion or œdema a very slight cause may produce necrosis. Invalids who suffer from acute diseases, particularly typhoid fever, may have extensive necrosis from comparatively slight pressure on projecting parts.

In consequence of necrosis of a tissue a more or less extensive inflammation is produced in the surrounding parts. This is more intense when putrefactive processes take place in the necrotic tissue, which exerts a

positive chemotactic attraction for the white corpuscles, which enter into it in large numbers. A zone of inflammation is set up which separates the necrotic tissue from its surroundings. The dead tissue may be gradually removed by absorption, or it may be cast off as a whole. A part of it may remain, which can afterward undergo calcification and remain in the tissues as a foreign body, and become surrounded by a capsule of connective-tissue formation, or a cyst may be formed in place of the necrotic tissue. This most commonly takes place in the brain, and it is also often seen in tumors.

One of the most common forms of necrosis is that designated as coagulation-necrosis. This is necrosis with coagulation of the necrotic cells and the fluid surrounding them. Both the cells and the cell-derivatives after necrosis has taken place may become changed into peculiar homogeneous, dense masses. Inflammatory exudations on a surface also unite with the necrotic cells of the surface and form masses of fibrin appearing as a membrane. The membrane consists partly of granules and partly of filaments, which are found united together to form thick meshes in the tissue. Large hyaline refractive masses can also form in this way. In this form of necrosis various changes take place in the cells. The nuclei first lose the normal arrangement of the chromatin, and become changed into solid masses which may stain more brightly than the nuclei of the normal cell. The nucleus appears solid and homogeneous. The nuclei afterward lose their sharp contour, become irregular, and finally break up into a mass of brightly-stained granules which may be recognized in the tissue as nuclear detritus. The best example of coagulation-necrosis is given in the infarction which takes place in various organs in consequence of the shutting off of the blood-supply. The cells may retain their form for some time. They afterward become changed into finely granular, homogeneous masses which may undergo absorption. Coagulation-necrosis takes a special form in striated muscular fibres. When necrosis of muscular fibres takes place in consequence of crushing or tearing, or of elevation of temperature in certain diseases accompanied by high fever, the contractile myosin becomes stiffened, and frequently changes into refractive homogeneous masses which may entirely fill up the sarcolemma. This form of degeneration is spoken of as the "waxy" or Zenker's degeneration. This may take place in the individual fibres of a muscle or may involve large masses of a muscle. It is a total destruction of the tissue, and is not capable of reparation. The affected muscles are of a pale grayish-red color somewhat similar to the flesh of fish, and have an opaque and dry appearance. This form of degeneration is frequently found in the muscles of the abdominal wall in typhoid fever. Hemorrhage usually takes place in the affected areas.

Another form of necrosis is known as "caseation." This term refers solely to the appearance of the necrotic tissue, and is used to designate a form of necrosis in which the tissue changes into a substance resembling soft white cheese. The best example of this is seen in the necrosis which takes place in tuberculous products. This caseous tissue is more or less brittle, and appears as an opaque whitish or yellowish-white mass. Caseation takes place when masses of cells with little or no tissue between them undergo necrosis. The consistency of the caseous tissue varies greatly. Sometimes it is firm and dry, sometimes comparatively soft.

Caseation cannot be regarded as a process peculiar to tuberculosis, although it is seen more often in tuberculosis than in any other condition. It is also seen in tumors which are rich in cells and contain necrotic areas due to disturbances in nutrition, and in the pathological products of syphilis, but the caseation which appears in the course of syphilis has a rather different character from that seen in tuberculosis. The necrotic tissue may undergo liquefaction. It becomes saturated with fluid, and finally melts up, forming a fluid mass. In an anæmic necrosis of the brain the necrotic tissue breaks up into small granular masses, which are partly absorbed and partly dissolved in the circulating lymph, and a cyst filled with clear fluid takes the place of the necrotic tissue. Coagulation does not take place, because the brain is so poor in the elements necessary to fibrin-formation. The chemical products produced in suppurative inflammation also have the power of dissolving necrotic tissue.

A peculiar form of necrosis is that known as fat-necrosis, and in connection with disease of the pancreas it has received much attention. Small opaque masses are found in the fat in various places in the abdominal cavity. They vary in size from a microscopic point up to areas several millimetres in diameter. On section of the pancreas they are also seen in the connective-tissue septa running through the gland. Fat-necrosis is associated with various diseases of the pancreas, with hemorrhage, with acute suppuration, and with other conditions. It is held by some authors that the changes in the fat are primary, and that the lesions in the pancreas are due to necrosis in the glandular septa. It is held by others that the lesions in the pancreas are primary, and that the necroses of the surrounding fat are due to the action of the pancreatic juice which escapes into the surrounding parts. The distribution of the areas of necrosis gives some ground for this assumption, but it has not been confirmed by experiment. The necrotic areas in the fat are intensely resistant. They are not affected by mineral acids nor by caustic alkalies. The peculiar change in the fat is due to a combination of lime-salts with the fatty acids.

Mummification, or dry gangrene, is seen in the senile necrosis of the lower extremities and the toes, and in the necrosis following frost-bite. Senile necrosis is due to imperfect circulation in the part, resulting partly from general weakness of the circulation and partly from disease of the intima of the artery with thrombosis, or from embolism. In frost-bite the necrosis is produced by the influence of low temperature lasting for a considerable time. In both frost-bite and senile gangrene there is venous hyperæmia while the necrosis is taking place. The necrotic tissue is filled with blood, and by the diffusion of the blood-coloring matter the necrotic part acquires a dark-red or black appearance. Vesicles are formed which rupture. The entire epidermis of the part may be removed, evaporation goes on rapidly, and the part becomes changed into a dry, hard mass with a leathery surface. A sharp line of demarcation is established between the healthy and the gangrenous tissue, and the gangrenous part may be gradually separated from the living tissues by suppuration and softening. The inflammatory exudation exerts a dissolving action on the necrotic tissue. The separation takes place readily through the soft parts, and in the course of time may extend

through the bones. Moist gangrene, or sphacelus, is characterized by decomposition or putrefaction in the necrotic tissue. This takes place when the organisms of putrefaction enter into a gangrenous part which contains a large amount of fluid. The gangrenous part may have its temperature elevated, this being due both to the process of decomposition and to a surrounding inflammation; and this condition is known as "hot gangrene." The putrefactive tissue soon begins to emit a foul odor and becomes broken down. Sometimes the process of decomposition is accompanied with the formation of gas, which may infiltrate the tissue. The various tissues of the gangrenous part show different degrees of resistance to the process of putrefaction. The bone may remain for some time, while the soft parts are rapidly broken down. The tendons and large arteries are also relatively resistant. On microscopic examination there are numerous bacteria present, most of which belong to the anaërobic forms. The blood-corpuscles become dissolved, broken up, and converted into masses of granular pigment. The fat-cells are broken down, and the fat appears in the form of small drops in the tissue. There are various crystalline products of this decomposition. We may find crystals of the fatty acids in the form of long needles, the needle-shaped crystals of tyrosin, the globular masses of leucine, and the coffin-shaped crystals of triple phosphates.

Hypoplasia is the condition in which portions of the body, or single organs or parts of organs, have an imperfect form of development in consequence of inhibition of growth. This may be due to intrinsic causes in the organs themselves resulting from imperfection in the germ, or it may be due to the influence of external causes. When organs or parts of organs are entirely absent, the condition is known as aplasia or agenesis. Examples of hypoplasia are seen in imperfect growth of the bones and in imperfect development of the heart or large vessels or of the genitalia or the central nervous system. The normal gradual development of a part may be interfered with and a fœtal condition of the organ result. The hypoplasia may affect organs which are necessary for life, or organs which serve some purpose not essentially connected with the preservation of the life of the individual. For instance, the genitals may remain in the fœtal condition or in that of early childhood. Hypoplasia may produce disturbances of function only, or it may be incompatible with life.

The condition of atrophy is usually separated from that of hypoplasia. Atrophy is a diminution in the amount of tissue, which takes place in an organ or part which has been normally developed. It may be due to an imperfect power of regeneration which cannot keep pace with the constant waste. Old age furnishes an example of this. There may be atrophy either of the entire body or of any of the individual organs or tissues of the body. An individual may die from old age without any preceding disease as soon as the atrophy of important organs reaches a condition which is incompatible with the proper performance of function. There is a physiological atrophy of certain organs which may take place in an early period of life. Certain organs which were necessary for life of the embryo undergo atrophy before birth. The sexual glands of the female may become atrophied and incapable of function long before the period of general senile atrophy is reached. The thymus gland atrophies

before the completion of the period of growth. Anatomically, atrophy is usually characterized by diminution in size of an organ. Microscopically, it is seen in the diminution in size, and finally the complete disappearance, of the specific elements of an organ. Atrophy may produce different appearances in different organs. In large organs rich in specific elements, as the liver, the kidney, the heart, and the brain, the diminution in size is the most striking feature. If the atrophy is a general one, affecting equally all parts of the organ, the surface may remain smooth. If it takes place only in certain parts of the organ, it gives to the surface an uneven appearance. The atrophied portions will be depressed, and the normal portions will appear correspondingly elevated. There may be atrophy without any macroscopic changes in form. A bone may atrophy without any change in its external size or shape, the atrophy having taken place in the interior of the bone by enlargement of the medullary canal. The bones of old individuals may be little more than shells enclosing a large medullary cavity. Diminution in the size of atrophied organs is usually due to destruction of their specific elements. The connective tissue of the organ may not take part in this atrophy at all; in some cases it may be even increased, so that an organ in which a considerable degree of atrophy has taken place may be of normal size or even larger than normal. This condition is seen in the pseudo-hypertrophy of muscles. In the atrophy of the kidneys which takes place in old age or in various other conditions the epithelial cells of the urinary tubules gradually become smaller and finally disappear, and the tubules collapse. The epithelium of the glomerulus also becomes destroyed, the capillaries collapse, and finally the glomerulus is represented by a small hard mass of connective tissue. Fat often undergoes a peculiar change in consequence of atrophy. The fat in the cell breaks up into small drops which become absorbed, and the cells freed from fat become transformed into their original character as connective-tissue cells.

Two forms of atrophy, active and passive, have been distinguished. In active atrophy there is a diminution in the capacity of growth and regeneration of the cells, in consequence of which they cannot assimilate the nutritive material which may be brought to them in the proper quantity. In passive atrophy the cells are capable of growth and regeneration, but there is a diminution in the amount of nutritive material which is brought to them. Both of these sorts of atrophy are frequently combined. Atrophy may be divided into senile atrophy, atrophy in consequence of imperfect nutrition, atrophy from pressure, atrophy from disuse, and neuropathic atrophy.

Senile atrophy may take place in all or any of the organs and tissues, but it is frequently more developed in some organs than in others. Organs such as the kidneys, the liver, the brain, and the heart can undergo very important diminution in size. Senile atrophy is also seen in the skin of old people, and this is one of the most common atrophic conditions produced by old age. The skin loses its firmness and elasticity and becomes thin and parchment-like.

Atrophy in consequence of disturbed nutrition is produced by imperfect assimilation. It may affect the entire organism or be more marked in certain tissues than in others. For instance, the fat of the body, the muscles, and the large abdominal glands show relatively a greater degree

of atrophy than the other tissues. Local atrophy may result from local interference with the circulation. An entire organ may undergo atrophy in consequence of diminution in calibre of its main artery brought about by disease, or only small branches of the artery may be affected, producing atrophy of circumscribed portions of the organ. Atrophy may be the result of pressure, even of comparatively slight degree, when it is constantly exerted. It is due partly to direct injury of the cells of the tissue in consequence of the pressure, and partly to interference with the blood-supply. The most typical example of this is seen in the broad band across the lower portion of the liver in women, corresponding to the line of the waist, and which is the result of the pressure of corsets. Sometimes this is so marked that there may be almost a complete separation of the lower portion of the right lobe of the liver from the rest. The atrophied part of the liver is marked by a thickening and roughening of the surface due to increase in the connective tissue. The firmest tissue may give way before a constant pressure. For instance, the pressure by an aneurism on bone, as in aneurism of the aorta pressing upon the sternum or upon the vertebræ, may produce complete atrophy and destruction of the bone.

Atrophy from disuse is seen in all tissues whose ordinary functions are suspended. It is more marked in the muscles, glands, and bones than in any other parts. The atrophy is essentially an active one. With the diminution in function the capacity of the tissue for assimilation also diminishes. There is also diminution in the activity of the circulation in organs with imperfect function, and the atrophy may be in part due to this. When the disuse appears during the period of development, and when the part in consequence is imperfectly developed, the condition may be regarded as one of hypoplasia. No sharp line can be drawn between atrophy and hypoplasia, since the hypoplasia of tissue may be associated with destruction of tissues which have already been formed. One of the best examples of atrophy from disuse is seen in the diminution in size of paralyzed parts.

Neuropathic atrophy is the result of pathological conditions of the nervous system. The best examples of neuropathic atrophy are seen in the atrophy of the corresponding nerves and muscles which follows atrophy of the anterior horn or anterior nerve-regions of the spinal cord. After injury of peripheral nerves the skin corresponding to their distribution may undergo atrophy and become thin and shiny. Affections of one side of the brain in fœtal life and in childhood may produce atrophy of the corresponding portions of the face and body. In this condition the process is not usually one of simple atrophy without any preceding change, but is preceded by various forms of degeneration, of which the atrophy represents the last stage. It is due to interference with the vasomotor system by which every part of the body exactly regulates its nutrition. Disuse of the parts and the greater susceptibility to trauma may also play an important part. Even for this form of atrophy it is not necessary to assume the existence of special trophic nerves.

Degeneration of Cells.—One of the forms of degeneration of cells is known as cloudy swelling, or parenchymatous or granular degeneration. The term was first used by Virchow, who regarded cloudy swelling as

an increase in the size of the cells produced by increased nutrition, or as hypertrophy with a tendency to degeneration, but the process is now regarded as degeneration. In cloudy swelling there is an increase in the size of the cells due to the accumulation of fine granules in the protoplasm. These granules are soluble in acetic acid and insoluble in caustic potash and ether. In consequence of the presence of the granules in the cells the nucleus is obscured, and it only becomes visible after the granules are cleared up by the addition of acetic acid. The process may be recovered from and the cells return to their normal state, or they may be converted into masses of granular material, and then break down and disappear. Fatty degeneration of the cells is frequently combined with cloudy swelling. It is best seen in the parenchymatous organs, such as the liver, the kidneys, and heart. It appears in most of the acute infectious diseases, especially in those which are accompanied with high fever. The affected organs have a cloudy, dull, grayish appearance. In the highest degree of the affection they look as though they had been boiled. The consistency is doughy and the minor details of structure are obscure. Cloudy swelling is frequently combined with a dropsical degeneration due to a swelling of the cells from the absorption of fluid. From the absorption of the fluid the interior of the cell appears clear and the granules of protoplasm are separated from one another and are sometimes pressed to the periphery of the cell. Such changes of the cells are found in œdematous tissue, in inflammatory foci, and in tumors.

Cloudy swelling frequently passes into fatty degeneration. In this fat-drops are formed in the cells, which finally break up into masses of fatty detritus. Certain tissues of the body normally contain a varying amount of fat. These tissues represent a storehouse for fat, which is either introduced from without or forms in the organism and is deposited in these places. An increase of this fat is not regarded as fatty degeneration, but as lipomatosis or obesity. Up to a certain degree it can be regarded as physiological. When it becomes excessive it represents a pathological condition. The deposit of fat takes place in the cells in the form of small drops, which gradually fuse together to form large globules, and finally a single large globule of fat may fill up the entire cell. The distinction which is made between lipomatosis and fatty degeneration is that in fatty degeneration the fat results from a destruction of the protoplasm of the cells by its conversion into fat. In the process of nutrition fat is probably formed by the destruction of albumin, but in fatty degeneration it is the albumin of the cell, and not the albumin of nutrition, which is broken up. Fatty degeneration especially takes place under conditions in which there is at the same time a tendency for the albumin of the cells to break down and a diminution of oxidation. It is frequently found in advanced phthisis, in which the oxidation in the tissue is greatly reduced on account of the destruction of lung-tissue. It is found in the varying forms of anæmia—both in the anæmia caused by direct loss of blood by hemorrhage and in other conditions in which the red blood-corpuscles are destroyed, causing a diminution in the amount of oxygen conveyed to the tissues. In the fatty degenerated cells there are larger and smaller drops of fat, which are colorless, dark, and refractive. When these drops are very small it is difficult to distinguish

them from the granules in the protoplasm seen in cloudy swelling, but on the addition of acetic acid the granules are cleared up and the fat can be distinguished. The number and size of the fat-drops in the cells vary, but in general the drops are very much smaller than we find them in the accumulation of fat. In some instances the fat accumulates in certain parts of the cell only. In fatty degeneration of the kidney the fat is formed in the periphery of the cells close to their insertion. The degeneration may not affect all of an organ, but only certain small areas, and these areas by their opacity and whiteness form a marked contrast to the surrounding tissue. This is frequently seen in the heart and in the kidney. In the heart the alternation of the fatty areas with the more normal tissues gives to the organ a spotted appearance which has been compared to that of a leopard skin or of a faded leaf. Fatty degeneration may take place in the voluntary muscles in anæmia and in other cachectic conditions, but it is more often seen in cases of disuse. Muscles which have been for a long time paralyzed undergo various degrees of fatty degeneration—a fact which points clearly to the effects of diminished oxidation.

In certain conditions glycogen may accumulate in the cells in the form of round globules. It can be recognized by hardening the tissues in absolute alcohol and staining with iodine, which gives to the glycogen a brownish-red color. Glycogen is normally found in the liver, in voluntary muscles, in the myocardium, in the colorless blood-corpuscles, in blood-serum, in cartilage-cells, and in almost all embryonic tissues. In diabetes the epithelium of the kidney, especially the epithelium of the tubules of Henle, may contain glycogen. It may be present in various forms of tumors, especially in the epithelial cells of carcinoma, and is more generally present in carcinoma of the testicle than in carcinoma elsewhere.

In mucoid or colloid degeneration there is a formation of material called mucus in the cells and in the tissues. The physiological type of this formation of mucus is seen in mucous membranes and glands, also in the tissue of the umbilical cord, in the various bursæ, and in synovial membranes. In mucous membranes the mucus is formed in the so-called goblet-cells. These are large swollen cells which have the appearance of a goblet, with a mass of mucus projecting from them. Apparently, this power of forming mucus exists in only certain of the epithelial cells. It may be increased under pathological conditions, as in catarrhal inflammation of the mucous membranes, in which there is an increased formation of clear mucus both in the surface epithelial cells and in the cells of the glands. Pus-corpuscles can undergo mucoid degeneration and mucin be formed in them. In certain tumors, as in the multilocular cysts of the ovary, there is an enormous formation of mucin. With regard to the formation of mucin in connective tissue, Virchow believes that it is formed by a secretion of the cells and is analogous to the formation of fat. Koester believes that in the mucoid degeneration of the connective tissue there is no new formation of mucin. The apparently mucoid tissue is really œdematous connective tissue, and the mucin already present in the tissues is swollen up by the imbibition of fluid. The term "mucoid degeneration" is one which is rather loosely used, and it is probable that various forms of degeneration of connective tissue

are included under this general head. Colloid degeneration is closely related to the mucoid. Its product appears to be derived from the metamorphosis of albumin, although we know nothing definitely of the chemical processes of its formation. It is formed from the cells, and physiologically it is always present in the thyroid gland, giving to a section of this gland a gelatinous appearance. It appears first in the epithelial cells of the gland in the form of small globules. The entire cell may undergo this transformation, or the single globules may be ejected from the cells and unite to form a large colloid mass in the centre of the alveolus.

A form of degeneration known as hyaline was first described by Recklinghausen. Its name indicates its most characteristic feature. It is a perfectly homogeneous material which has rather indefinite staining reactions. It stains with eosin, with carmine, with picrocarmine, and with certain of the acid anilines. It has the same reaction to alcohol and various other agents as has the amyloid material, but it has not the characteristic stain with iodine which the latter has. It is very probable that the hyaline material embraces a number of different products. It is found in certain epithelial tissues, where it is closely related to the colloid material, if not identical with this. In certain forms of nephritis a homogeneous, firm material accumulates in the urinary tubules and is passed from the kidneys, appearing in the urine as hyaline casts. This material has apparently been formed by a degeneration of the protoplasm of the cells, and appears first within the cells in the form of small homogeneous drops. There may be a similar process in the lungs. In certain forms of pneumonia in cattle the alveoli may become filled with firm, transparent, homogeneous masses. Large epithelial cells containing in their interior homogeneous globules may be found enclosed in the hyaline masses, which probably are derived from coalescence of hyaline globules formed in the epithelial cells. The material described as hyaline in some cases seems to be identical with or closely related to fibrin. It may appear in the form of homogeneous masses which entirely occlude small blood-vessels. This is frequently seen in the blood-vessels of the lungs in various infectious diseases, especially in those due to infection with streptococci. It is also seen in the blood-vessels of the kidney, where it occludes the capillary vessels of the glomeruli. This form of hyaline material stains in the same way as fibrin, and it is probable that it is identical with it. The newly-formed connective tissue in chronic inflammations may be converted into a homogeneous, firm mass in which no cells are found. This is also spoken of as hyaline, but it must be regarded as entirely different from the other forms of hyaline. It is probable that we shall know little of these forms of degeneration until the chemistry of the process shall be in some way discovered.

Amyloid Degeneration.

Under certain conditions a peculiar albuminous substance, called amyloid, is deposited in the tissues. This deposition may take place in almost all the organs of the body, but appears most often, in the order given, in the spleen, the liver, the kidneys, the intestine, the stomach, the adrenal glands, the pancreas, and the lymph-glands. It is more rarely

seen in the adipose tissue, the thyroid, the aorta, the heart, the muscles, the ovaries, and the uterus. It may take place in organs which are the seat of some other disease or in those which were previously sound. The amyloid material is generally found along the small blood-vessels, especially in the walls of the small arteries. At first sight it appears as though the entire wall of the artery were converted into amyloid, but closer examination will show that the amyloid material is infiltrated between the muscle-cells. Though spoken of as a degeneration, it really is not produced by a metamorphosis of the tissue, but is an infiltration which is deposited between the cells of the tissue and gradually produces atrophy in them. It is frequently combined with other forms of degeneration, especially the fatty. Even though an organ be sound when the deposit of amyloid first takes place, this deposit, from its position, situated as it is about the blood-vessels, will lead to such disturbances of the circulation and nutrition of the organ that other forms of degeneration will occur. If a section of such an organ, either fresh or after hardening in alcohol, be treated with an aqueous solution of iodine, the amyloid material becomes a reddish-brown mahogany color, contrasting sharply with the normal tissue, which has a slight yellowish tint given it by the iodine. If amyloid material so stained be treated with a dilute solution of sulphuric acid or with chloride of zinc, the brown color sometimes becomes more intensified or it may take a slight violet tone. A more direct reaction is given by any of the blue aniline colors, especially gentian-violet. Fresh sections of the affected tissue may be placed in the coloring agent and afterward washed out in very dilute acetic acid. The amyloid substance acquires a brilliant red color, and contrasts sharply with the normal tissue, which has the ordinary blue stain. The situation of the amyloid in the walls of the arteries would seem to indicate that it is formed either in the blood or in some special organ, and afterward deposited in the walls of the vessels and in the tissues. We do not know, however, any organ in which such a formation could take place. The most prevalent view now held concerning it is that it is formed from the albumin in the place where it is found. The cells seem to lose their power of properly assimilating albumin, and it undergoes this peculiar form of degeneration. The conditions under which amyloid infiltration takes place are well known. It is always found in cachectic conditions of the body brought about by long-continued suppuration or by certain chronic diseases. It is rather more frequent in syphilis than in any other disease, and it is rare that we find any extensive visceral lesions of syphilis without finding a certain amount of amyloid in the tissues. It is especially apt to occur in the chronic affections of bone. The recognition of amyloid infiltration of tissues is very important. The nutrition and general resistance of the tissues are so impaired that surgical operations and injuries usually are not well borne.

The amyloid material may also appear locally, producing localized infiltration of the tissue or solid accumulations of amyloid. Large nodules which are entirely composed of amyloid may form in the tissues. Such nodules have been seen in the inflamed conjunctiva, in syphilitic cicatrices of the liver, in the tongue, in the larynx, and in inflamed lymph-glands. In cicatricial tissue, changes which appear to indicate

preceding stages to amyloid formation may be seen. Instead of a perfectly definite color-reaction with gentian-violet, there may be only a slight reddish or mahogany tint given to the tissues. The corpora amylacea are composed of a substance either amyloid itself or closely related to it. These are small, firm, round bodies which vary considerably in size, are formed normally in the prostate gland, and have a concentric structure which gives them a striking similarity to starch-granules. They have nothing to do with the general amyloid disease, and are formed in consequence of local conditions in the tissues. In the prostate they appear to be due to accumulation of degenerated epithelium.

Calcification.

Lime-salts may be deposited within the tissues in the form of a general infiltration which is spoken of as calcification, or in the form of masses not connected with the tissues and which are called concrements, stones, or calculi. Calcification never takes place in perfectly normal tissues, but the deposit of the lime-salts is always preceded by necrosis. It is probable that the necrotic tissue undergoes certain modifications in its chemical reaction, in consequence of which the lime-salts held in suspension in the fluids of the tissue are deposited in it. Calcification is especially apt to take place in dense cicatricial connective tissue which is poor in cells and nuclei. It is also frequently seen in the degenerated tissue in the walls of the blood-vessels, in tumors, and, in fact, everywhere where there is necrotic tissue. The infiltration may be found only in the intercellular substance, the cells having disappeared, or in some cases it is found in the cells themselves, the intercellular substance being little or not at all affected. One of the most frequent places in which the lime-salts are deposited is in the walls of the large arteries and in the left side of the heart. It would appear, at first sight, as though there might be some connection between the lime-salts and arterial blood, but the truth is that the various forms of degeneration of the blood-vessels and the endocardium are more common in the left side of the heart and in the arteries than in the right side of the heart and in the veins. Thrombi may become calcified, forming vein-stones or phleboliths, and the necrotic tissue of an infarction may also become completely calcified. In general, calcification takes place in the lower animals, especially in the herbivora, to a much greater extent than in man. In gout there is a deposit of the urate of soda in the tissues. This may take place in the kidneys, in the skin, in the subcutaneous tissues, in the tendons, the ligaments, the synovial membranes, and the cartilage of the joints. The favorite seat of the deposit is in the metatarso-phalangeal joint of the great toe. It is probable that the deposit takes place principally, if not exclusively, in tissues which have undergone necrosis. It appears in the form of long, slender, needle-shaped crystals. A formation of free concrements or calculi can take place in the various canals and cavities of the body which are lined with epithelium. Such concretions may form in the intestinal canal, in the ducts of the large intestinal glands, in the gall-bladder, in the urinary tract, and in the respiratory passages. All of these concrements have an organic basis, and lime-salts are deposited in this material. In the intestinal glands the calculi consist

of a deposit of lime-salts around thickened fæces or various undigested vegetable masses. The most frequent place for the formation of concrements is in the gall-bladder, which may contain but one or may be filled up with large numbers of them. When there are several present their surfaces become faceted by mutual pressure.

These gall-stones are usually composed of cholesterin united with various constituents of the bile. In rarer cases they are formed from carbonate of lime. After the cholesterin is dissolved there still remains a homogeneous substance. There can be no doubt that the formation of gall-stones is due to the incrustation of an organic mucoid substance with the constituents of the bile. Colon bacilli have been found in gall-stones.

The most important concrements and calculi of the body are those found in the urinary passages. They may form either in the kidney, in the ureter, or in the bladder. In the kidney they not infrequently form large irregular masses which may fill up the entire pelvis of the kidney and extend into the calyces, or only small masses may be formed. Concrements appear in the tissue of the kidney itself in the form of very small masses, which may either lie in necrotic epithelium or in the lumen of the tubules. In the so-called uric-acid infarction of the kidney, which is so common in children who die in the first week of life, there is simply a deposit of urinary sediment in the occluded tubules. The large calculi formed in the urinary bladder consist of an organic substance, probably related to albumin, in which various salts are deposited. What sort of material will be deposited in these masses depends upon circumstances. If large amounts of uric acid are excreted, as in the uric-acid diathesis, calculi may form composed of this. When there is decomposition of the urine in the bladder, with the production of triple phosphates, calculi can be formed of this substance. When a calculus has once been formed the irritation which it produces is favorable to its increase. All sorts of foreign bodies introduced into the bladder can serve as nuclei for the formation of calculi.

Pigmentation.

Many of the normal tissues of the body, both connective tissue and epithelium, contain a certain amount of pigment. The pigment is almost always contained in the cells, and consists of brown or dark amorphous granules. Examples of such pigmentation are found in the hair and in the choroid of the eye. The nerve-cells in the central nervous system contain a small amount of pigment, and pigment is also contained in the cells of some of the glands. The skin may show a general pigmentation, or the pigment is seen only at certain places; for instance, in the axilla and over the scrotum. During pregnancy the pigment of the skin, especially in brunettes, undergoes a considerable increase. There may be a marked increase in the pigment brought about by certain diseases, as in Addison's disease, in which lesions may be found in the suprarenal capsules or in the semilunar ganglia. The pigment of the heart shows considerable increase in certain forms of atrophy of the myocardium, especially in the atrophy of old age. Pathological pigmentation is also seen in the freckles of the skin and in the congenital pig-

mented moles. Certain tumors belonging to the sarcomas also show a marked degree of pigmentation. The pigment may be brown or show every degree of transition up to perfectly black masses. It usually lies in the cells, and rarely in the intercellular substance. When it is found in the intercellular substance, it is probably due to its being set free by rupture and destruction of cells. The formation of pigment seems to be, in the main, a property of cells belonging to the connective tissue. In the skin, although the pigment may be contained in or between the epithelial cells, it appears to be formed in large branched cells in the subcutaneous tissue. The source of the pigment has not been in all cases definitely ascertained. It is true that pigment may be formed from the blood-coloring matter, but hemorrhage is not generally found in the areas where pigmentation is taking place. The pigment which is derived from the blood under ordinary conditions is usually brown or reddish-brown, and has not the deep-brown or black color found in other conditions. Chemical investigation has shown that some of the pigment contains iron, while other pigment is free from it. The blood-extravasation which takes place in an ordinary bruise undergoes various changes of color. When the extravasation has taken place in a transparent tissue—for instance, in the pleura or in the peritoneum—a rusty-brown color may remain for a long time afterward. All these changes in color correspond to physical and chemical alterations of the hæmoglobin and the iron contained in this. When hemorrhage takes place in the tissues, the red blood-corpuscles may be taken up by the lymphatics in an unchanged condition, or the hæmoglobin may be dissolved out of them and taken up by the circulation. It is this dissolved blood-coloring matter which produces the various changes of color in the neighborhood of blood-extravasations. Blood-crystals may be formed from the extravasated blood, and they are frequently found in the remains of old hemorrhages. In cases of chronic passive congestion there is usually a certain amount of diapedesis, and a brownish color may be given the tissues by the presence of the blood-pigment. The best example of this is seen in the chronic passive congestion of the lung, the salmon-brown color in this being due to the presence of large cells in the alveoli of the lung, which are filled with brownish-red or brownish-yellow pigment. In jaundice or icterus the pigmentation is due to the coloring material of the bile. During life this is easily recognized in the skin and in the conjunctiva. When the jaundice first appears the tissues have a bright-yellow color, and after it has existed for some time this changes into an olive-green or a grayish-green color. Jaundice is usually due to some condition which interferes with the passage of the bile and leads to its absorption into the lymphatics of the liver, and from this into the blood. Swelling of the mucous membrane of the bile-ducts, due to catarrhal inflammation, narrowing or closure of the bile-ducts by cicatrices or by the presence of gall-stones, tumors developed in the bile-duct, or the pressure of tumors outside of the ducts, may all be followed by jaundice. The common bile-duct is comparatively large and thin-walled. The pressure of the bile within it is very low, and a very slight degree of distention will lead to the retention of the bile and its absorption. According to various authors, there is a form of jaundice, the so-called hæmatogenous jaundice, which is produced by the conversion of the hæmoglobin of the blood in

the blood-vessels into bile-coloring matter. The results of experiments have tended to show that a pure hæmatogenous jaundice does not exist, but there may be a destruction of red blood-corpuscles in the blood, and the hæmatoidin thus set free is converted in the liver into bilirubin and then absorbed.

The tissues may also become pigmented from pigment which is taken into the body from without and absorbed in the tissues. The pigment may enter the body by means of the respiratory or intestinal tract and from wounds. In the operation of tattooing the skin is broken and insoluble coloring material is rubbed into the wounded surface. A portion of this material remains in the tissues at the place, and a portion is taken up by the lymphatics and carried to the adjacent lymphatic glands. In case the arm is tattooed the epitrochlear and the axillary glands always contain the same pigment which is rubbed into the skin. The lungs may undergo a marked pigmentation in consequence of the inspiration of dust and particles of carbon. A part of the dust remains in the lungs, and is found both in the walls of the alveoli and in the thickened and indurated tissue which results from the chronic inflammation set up by the presence of the foreign particles. A part of the material is carried to the nearest lymph-glands and produces pigmentation of these.

An interesting form of pigmentation is due to the introduction of silver salts into the body. When nitrate of silver has been used medicinally for some time, the skin acquires a grayish-brown appearance and the organs may also become pigmented. The silver is deposited in the form of fine granules in the tissues of the organs.

In malaria there is a formation of pigment in the blood. This condition is found in all forms of malaria, and is due to the destruction of the red corpuscles by the malarial parasites which inhabit them. The pigment which is formed is derived from the hæmoglobin. It is found both in the red and white corpuscles. In the red corpuscles it is found in the parasites which they enclose. In the white corpuscles the pigment is also derived from the parasites, the pigment produced by them in the red corpuscles being taken up by the white corpuscles. In certain stages of the disease pigmented parasites may also be found free in the blood. The pigment is also deposited in certain organs of the body, notably in the spleen and in the liver.

VI. TUBERCULOSIS AND TUBERCLE.

Tuberculosis is an infectious disease produced by the tubercle bacillus. It is characterized by the formation of larger and smaller circumscribed nodules called tubercles, by more diffuse formation of tissue of the same character as that composing the nodules, and by various forms of inflammation. The word "tubercle" was first used without any specific meaning to describe a small nodule. In 1796, Baillie, the nephew of John Hunter, gave the first description of tubercle as found in the lungs. It was noticed that these tubercles were frequently found associated with a destructive disease of the lungs, and finally both the tubercles and the destruction of lung-tissue accom-

panying their presence were referred to one and the same cause. Afterward nodules of a similar character were found in the lymph-glands, in the tissues of diseased joints, and in various other places in the body. It was found that wherever these nodules appeared they were composed essentially of the same sort of tissue, and that they were particularly prone to a form of degeneration by which they became changed into a substance resembling certain sorts of cheese. Tissue of the same general character as the tubercles was also found, not in circumscribed masses, but rather diffusely, and it was found that this tissue also underwent caseation. When inflammation accompanied the process the products also became caseous. There is no doubt that although the form of degeneration called caseation is not a specific process limited to the tuberculous tissue, it so commonly takes place in this that it has served more than any other morphological factor to unite under one head the various manifestations of the disease. The conception of tuberculosis as an infectious disease was founded on the anatomical study of the disease and its mode of progression before the discovery of the specific organism. Even twenty years before the discovery of the bacillus it was found that a disease agreeing in all essential respects with the disease as found in man could be induced in rabbits by inoculating them with the products of the disease from man.

It is now universally acknowledged that a bacillus is the cause of the disease. This was demonstrated by Koch in 1881, and all the work which has since been done has served to confirm the work of Koch. The bacillus tuberculosis is one of the smallest of micro-organisms. It is from one-quarter to one-half the diameter of a red blood-corpuscle in length, and the length is usually five or six times the breadth. The bacilli are usually somewhat bent and the ends are rounded. Special methods of staining are necessary to demonstrate them. A great many methods have been given, but they all consist in the use of fluids which stain intensely, followed by decolorizing solutions which remove the color from everything but the bacilli. When stained the bacilli may be of a homogeneous color, or they may show an alternation of intensely stained particles and clear spaces. These clear spaces were first supposed to represent spores, but it is doubtful whether they should be so considered. It is probable that there is no growth of the organisms outside of the body under ordinary circumstances. Special media and an elevated temperature are necessary for their growth, which is very slow, there being usually no indication of it for several weeks. There is a great difference in the susceptibility of different animals to the disease. Guinea-pigs are among the most susceptible, and these succumb in from six weeks to three months after inoculation.

For a long time no typical structure was regarded as characteristic of tubercle. Virchow described the tubercle as a nodule composed of small round cells similar to those found in granulation tissue, and derived from multiplication of the connective-tissue cells, and called attention to the tendency of the cells in the centre of the nodule to undergo necrosis. As the methods of histological investigation improved tubercle was studied more closely, and it was found to have a more or less typical structure. Langhaus gave a more detailed description of certain large multinucleated cells commonly found in tubercle; a

peculiar reticulum between the cells was described by other observers. When a very young miliary tubercle is examined after suitable methods of hardening, a reticulum is seen, in the meshes of which the cells lie. The extent to which the reticulum is developed depends upon the age of the tubercle and the character of the tissue in which it develops. It may be as firm and definite as the reticulum of a lymphatic gland, and in other cases scarcely a trace of it may be seen. There are various sorts of cells in the nodule, the most prominent of which from their number are the epithelioid cells. These are cells somewhat resembling epithelial cells; they have a pale, finely-granular or homogeneous protoplasm and large oval vesicular nuclei. The arrangement of these cells with reference to the reticulum varies. Sometimes they appear to lie in the meshes of a more or less fibrous reticulum; sometimes they form the reticulum. The cell-outlines are never clear and distinct; the cells are usually fused together. The epithelioid cells are also found, not as distinct groups, but more or less scattered in the tissue. Among the epithelioid cells, lying between them or in the meshes formed by their union, are round cells similar to those found in young granulation tissue. These cells vary in number, and are most abundant in the periphery of the nodule. The large, multinucleated giant-cells are a prominent feature of the tubercle. Sometimes one of them forms the centre of the nodule, and has long processes which communicate with the reticulum; or they may be perfectly round, without processes, and lie in a space surrounded by epithelioid cells. In some cases they are situated in the periphery of the nodule. The nuclei of the giant-cells are either arranged around the periphery, with their long axis perpendicular to the centre, or they are grouped in masses at either end of an elongated cell. The histogenesis of the tubercle has been carefully studied, but we are still far from completely understanding it. Baumgarten considers the epithelioid cells as the most important cells found, and that they are derived from the pre-existent cells of the tissue under the influence of the tubercle bacilli. They may be formed from the epithelial cells of glands, from the connective-tissue cells, or from the cells of the blood-vessels. According to Baumgarten, the first step in the formation of a tubercle is the presence of tubercle bacilli in the tissue. These enter into the fixed cells, no matter what the character of these may be, and produce cellular proliferation, the newly-formed cells being the epithelioid cells. The production of the giant-cells is a more obscure process. Weigert thinks that they are produced by the proliferation of degenerated cells, the nucleus dividing without separation of the protoplasm. In some cases they appear to be produced by fusion of the epithelioid cells, and they are undoubtedly sometimes formed in blood-vessels, and may be traced in continuity with vessels. They are probably formed in a variety of ways. The small round cells, found in varying numbers in the tubercle, are derived, like the granulation-cells, from multiplication of the connective-tissue cells in the tissue in which the tubercle is formed. Little is known of the formation of the reticulum. It is probably in large part composed of the remains of the connective-tissue fibres which have been pressed apart by the proliferating cells. It may be in part newly formed by the cells of the tubercle, which for the most part are derived from the connective tissue and under ordinary circumstances would form such tissue.

The tubercle is a non-vascular structure. The blood-vessels which are present in the tissue where the tubercle develops become occluded by thrombosis or from the pressure of the numbers of cells, and no new blood-vessels make their way into it.

This description of tubercle applies to very young nodules in which no degeneration has taken place. The first evidence of such degeneration is shown in hardened specimens by the nuclei of the cells in the interior staining less brilliantly. In sections of fresh tissue more or less extensive fatty degeneration of the cells in the centre is found. The nuclei cease to stain, and the cells fuse together in a solid homogeneous mass in which no cell-outlines can be seen. The form of degeneration is that described by Weigert as coagulation-necrosis, and it is always preceded by fatty degeneration. A zone of closely-packed fat-molecules is always found around the necrotic centre. In the giant-cells the same process seems to take place. The centre is similar to the necrotic centre of the tubercle, and around this, just inside the nuclei, there is a zone of closely-packed fat-granules.

Macroscopically, the tubercle when very young is pale, transparent, and with difficulty distinguished in the tissue. When degeneration begins it is white, opaque, and easily seen. The white color is not due to the absence of vessels alone, but rather to the presence of the fat-molecules.

With the appearance of degeneration in the tubercle another cellular element enters into it. This is the polynuclear leucocyte. Necrotic tissue, however caused, exerts a positive attraction on the leucocytes, and the necrotic tissue in the tubercle has the same power. The polynuclear leucocytes may be recognized by their irregularity in form and by the brightness with which they stain. They enter into the tubercle and into the necrotic tissue, often forming a definite ring around the latter. In the degenerated area they seem to undergo the same fate as the other cells. The nuclei break up into fragments and form the small, brightly-staining granules seen in the tissue. Occasionally they may be found within the giant-cells.

The fatty degeneration and caseation to which the tubercle is so prone has been attributed principally to the absence of blood-vessels. Although this may play a part, the degeneration of the tissue cannot be attributed solely to this cause. We find other structures in the body, of the same size as, or even larger than, the tubercle, in which there are no vessels and which do not show the same tendency to degeneration. The necrosis of the cells is due more to the influence of the bacilli or their chemical products on the tissue than to the absence of blood-vessels.

The relation of the tubercle to the surrounding tissue differs. In most cases there is around it a well-marked zone of granulation tissue filled with round cells which become more abundant in the periphery of the tubercle, and finally merge into the surrounding granulation tissue without a sharp line of demarcation. As the tubercle increases in size the central caseation increases in extent and the granulation tissue changes into that of the tubercle, the round cells becoming epithelioid in character.

The tubercle may undergo other forms of degeneration than the caseous. The entire mass may become converted into a perfectly smooth hyaline substance, or, before necrosis takes place, connective tissue may

be formed from the cells, and such tubercles, even after caseation, are much firmer and harder than those in which the necrotic tissue is composed of cells alone.

The number of tubercle bacilli in the tissue varies; they may be present in large numbers or may be absent altogether. As a general rule, they are not so numerous in the youngest tubercles as they are in those in which degeneration is well advanced. In certain places they seem to be absent as a rule. In acute miliary tuberculosis of the liver I have frequently not been able to find a single bacillus in any of the numerous tubercles in the tissue. It is probable that under certain conditions they are destroyed by the tissue, or they may become so changed as to be no longer recognizable. The bacilli occupy no constant position in the tissue; they may be found within or lying between the epithelioid cells. Sometimes a mass of them may be seen in the centre of the caseous mass, or the giant-cells may contain them in varying numbers.

The miliary tubercles may appear alone, or in numbers forming the large conglomerate tubercles. Most of the tubercles which are visible to the naked eye are composed of several nodules united together. These larger conglomerate nodules are formed around a single tubercle which seems to serve as a focus of infection. The tubercle bacilli from this are carried, either by the lymph-stream or enclosed in wandering cells, into the surrounding tissue, in which numbers of tubercles are thus developed. As the caseation in the individual tubercles advances it affects also the tissue lying between them, so that finally a large caseous area is formed which is surrounded by a zone of miliary tubercles. The large solitary tubercles which are frequently found in the brain, and less frequently in the liver and other parts of the body, are formed in this way. Although the miliary tubercle is the most characteristic of the lesions produced by the tubercle bacillus, it forms but a small part of the lesions of the disease. The formation of a tissue similar to that of the miliary tubercle, and which appears not as a nodule, but as a diffuse infiltration of the tissue, is a much more prominent part of the process. The formation of this tissue is closely related to inflammation. Where in an ordinary inflammation there would be a formation of granulation tissue, under the influence of the tubercle bacillus a tissue composed of epithelioid and giant-cells, and which is peculiarly prone to necrosis and caseation, is produced. In tuberculosis of the joints the pale masses of granulation tissue around the joints show on the outside a narrow rim of caseation, and back of this a tissue composed largely of epithelioid and giant-cells. In this tissue there are frequently circumscribed tubercles.

Not only is the tubercle in its formation closely related to inflammatory new formations of tissue, but it is always accompanied by inflammation. The nodular tubercle as a foreign body excites inflammation around it. The zone of granulation tissue around a tubercle is the result of a reactive inflammation of the tissue. The chemical substances which are produced by the bacilli and in the tuberculous tissue may exert a non-specific but simply injurious action on the surrounding tissue, which will be followed by inflammation. The bacilli themselves, instead of causing the more typical tissue-formations, may excite inflammation. The form of inflammation varies. In some cases an exuda-

tion containing fibrin in varying amounts may be produced; in other cases a typical suppuration. In no other tissue in the body is this intimate association with inflammation so evident as in the lungs. Apart from the presence of miliary tubercles, which ordinarily play but a small part in the process, the lesions of pulmonary tuberculosis are chiefly inflammatory. The greater part of the lesions is due to tuberculous pneumonia, in which there is consolidation of the lungs, due to exudation and accumulation of cells in the alveoli. The exudation in some cases contains much fibrin; in others it may be chiefly serous, or the alveoli may be filled with a hyaline gelatinous substance. The cells within the alveoli are chiefly large, pale, epithelioid cells, mingled with both white and red corpuscles. In some cases, especially on serous surfaces, the exudation is chiefly hemorrhagic. Always, particularly in the lungs, along with the inflammatory processes due directly to the action of the tubercle bacilli and their soluble chemical products, there are inflammatory lesions due to conditions which the bacilli create.

The inflammatory tissue produced in the lungs by the bacilli undergoes the same caseation as the tubercle. It becomes converted into a dry, homogeneous, necrotic mass. The fibrin becomes enclosed in it, and may still be recognized in the caseous tissue by appropriate methods of staining. On microscopic examination of the brittle caseous mass the anatomical structure of the tissue composing it may still be recognized. In the lung the walls of the alveoli appear, dividing the caseous tissue into small areas. The caseation follows the same course as in the tubercle, commencing in the centre and gradually extending to the periphery. An entire lobe, or even an entire lung, may be converted into a solid, necrotic mass of tissue.

The caseous tissue does not tend to remain, but after a variable length of time it undergoes softening. The cause of this is not fully understood. The dry, caseous tissue becomes converted into a soft, fluid, puriform mass. On microscopic examination fragments and detritus of tissue and cells may be recognized, with here and there a few well-preserved leucocytes. The cause of the softening may be due to changes taking place in the tissue spontaneously or to the action of influences from without. The necrotic tissue forms a favorable seat for the action of other microorganisms which can gain access to it by the bronchi. The softening may be distinctly purulent; there may be a purulent inflammation in the tissue around it, and the caseous matter may be dissolved in the purulent exudation. As soon as softening takes place favorable conditions for further infection are produced. Not only are the tubercle bacilli present in the softened material, but there are other organisms. It is probable that even without the presence of organisms the chemical products present may exert a deleterious influence on the tissues. Bronchi always open into the softened area, and offer a direct route for infection of other parts of the lungs. To the specific action of the various substances in the softened tissues must be added the effects which may be produced by the mechanical action of solid particles occluding the small bronchi. It is easy to see why in such a tissue as that of the lungs tuberculosis should produce such a variety of lesions.

There is probably no disease in which there is such a variety in the lesions as is found in tuberculosis. A careful study of the lung-lesions

in a case of chronic tuberculosis would show nearly all the pathological processes. The course of the disease also varies. In some cases it may advance rapidly and lead to death in a few months or even weeks; in other cases it pursues the most protracted course, may continue during the entire life of the individual, and in the end only indirectly contribute to death. All of these differences in the effects of infection with the bacillus depend upon a number of factors.

All individuals are not equally susceptible to the disease. It was formerly generally believed that the disease itself was inherited, but it is more probable that not the disease itself, but a greater or less susceptibility to the disease, is inherited. Other things being equal, children of tuberculous parents, especially if the disease has been in the family for a number of generations, are more liable to be affected with tuberculosis than the children of parents who were free from this disease. This special susceptibility or tendency may not be expressed in any other weakness or habit of the body: such children, born of parents in good circumstances of life, may develop strong and robust bodies with more than the average powers of endurance. One factor must always be considered—namely, that in general these children have greater opportunities for infection if they are living in the house with tuberculous people. It is also probable that certain races show a greater susceptibility than others to this disease. In this country certainly the colored and the Celtic races seem to be more liable to the disease than any other, while the Jewish race appears to possess a certain degree of immunity against it. The same thing is true of cattle. The cattle coming from the Channel Islands, the Alderney and Jersey stock, especially the pure breeds, have much more of the disease among them than any other breeds.

It is probable that there are also differences in the virulence of the bacilli in different cases. Even inoculations on guinea-pigs of the same age with the same amounts of virus from different sources show differences in the course of the disease.

The course of the disease will further be influenced by the manner in which the organisms gain entrance into the tissue. They may enter it by means of canals or ducts which communicate with the outside, or by the blood- and lymphatic vessels. In this way either tuberculous inflammations or miliary tubercles may be produced. It is probably not necessary to have an actual lesion of continuity for the bacilli to pass into the tissue. It has been shown that the disease can be produced by rubbing the organisms on the skin of a rabbit. Tuberculosis of the alimentary canal in man probably takes place without any preceding lesion. The tubercles here appear first in the lymph-glandular tissue of the gut, and no lesion of the mucous surface may be visible. Not only is there a general difference in the susceptibility of the tissue of different individuals, but there are differences in the different tissues of the same individual. Some tissues are almost exempt. In certain cases tubercle bacilli may be found in great quantities in the blood, and miliary tubercles be formed all over the body, except in the muscles. The ovary shows a relative immunity, and the pancreas and thyroid are rather rarely attacked. It cannot be that these organs are protected from the entrance of the bacilli, for in cases of infection by the blood they are

equally liable to have the bacilli carried into them. None of the tissues enjoy an absolute immunity. Even the muscles may be invaded by the gradual extension of tuberculous foci into them. In a tuberculous ulcer of the tongue tubercles are found in the muscular tissue for quite a long distance beneath the ulcer. In cases of joint tuberculosis also the adjacent muscles may be involved by the extension of the disease.

There is always some primary focus of the disease in the body. The primary seat of the disease in most cases is in the lungs, but it may commence in almost any other organ of the body. From the primary focus the infection extends, following various routes. There may be infection of the tissues in direct continuity. The bacilli may be carried enclosed in cells, or they may extend by growth into the tissue adjoining, and in this way large tuberculous nodules may be formed. The bacilli may pass along the lymphatics, either into the surrounding tissue or into the lymphatic glands into which the lymph-vessels empty. The infection of the lymphatic glands almost surely takes place, and in many cases they may present the only evidence of the disease. In tuberculosis of the lungs the bronchial glands are always affected: if the intestine be affected, the mesentery glands are tuberculous. In many cases the bacilli are probably carried directly to the lymph-glands from the seat of entry without producing any lesions where they have entered. It is probable that in many cases the bacilli gain entrance into the tissues through the mucous membrane of the mouth or pharynx, and the first evidence of the disease is in the cervical glands. The glands appear to protect the organism from further infection for some time. The tissue of the lymphatic glands offers a suitable locality for the growth of the bacilli. Extensive lesions are produced in them, and finally the glands serve as foci for further infection. The glands next in order become affected, and in this way all the lymphatics and lymph-glands up to the thoracic duct may gradually become tuberculous; and finally the bacilli are carried directly into the blood. In most cases the infection follows in the direction of the lymph-current, but it may also proceed against the stream.

Infection may also take place by the bacilli being carried along open canals or ducts from one part of an organ to another or to various parts of the body. The lungs offer the most suitable conditions for this mode of infection. The primary seat of the disease in most cases is in the apices, and when softening of the caseous tissue takes place the detritus, full of bacilli, may be carried by aspiration into every other part of the lungs. The bacilli are contained in the sputum, and further infection both of the air-passages and of the alimentary canal takes place from this.

This mode of infection is seen also in the genito-urinary tuberculosis in the male. Here, in the majority of cases, the primary seat of the disease is in the epididymis. It may be confined to this, or the testicle may be affected by continuity. The epididymis is converted into a more or less firm, caseous mass. From this the disease extends along the vas deferens, which becomes enlarged, and on section the interior is found to be lined with a whitish caseous tissue. In both the vas deferens and epididymis the seat of the disease is primarily in the epithelium and takes the form of a tuberculous inflammation. The seminal vesicles on the same side

become affected in most cases, or they may be passed by and the disease appear in the prostate or bladder. Up to this point it is easy to see how the infection has taken place: the extension has been in the direction of the secretion, and the bacilli could be carried along with the secretion. From the bladder the extension is in a direction opposite to the flow of the secretion. With or without any involvement of the ureter infection of the pelvis of the kidney and of the adjoining kidney-tissue takes place. It is probable that the bacilli find suitable conditions for growth in the ureter, and grow along the walls, just as on the surface of a solid medium, until the pelvis of the kidney is reached. There is no other way for infection to take place from the bladder to the kidney than along the ureter. There is no lymphatic or vascular connection. The proof that this is the usual route of infection in genito-urinary tuberculosis is shown by the certainty with which the disease can be traced step by step, and the extreme rarity of the disease in females as compared with males. In some cases the disease appears to be primary in the kidney, and the infection may take place in the opposite direction.

The blood plays an important part in the extension. Sometimes the bacilli gain entrance into the blood from the lymphatics. The more common way is by a direct infection of the blood. Tuberculosis of some of the large veins of the body may take place, the vein being affected by the extension of a tuberculous process in an adjoining tissue. The bacilli are carried by the blood into all the organs of the body, and a general miliary tuberculosis is the result. Even in this some of the tissues are exempt. Miliary tubercles are never found in the muscles or in the skin, and only rarely in the alimentary canal or in the ovaries. Infection by the blood may take place without the production of a general miliary tuberculosis. In almost every case of extensive tuberculosis a few tubercle bacilli probably enter into the blood. These will be deposited chiefly in those organs in which the conditions of the circulation are most favorable for the retention of fine solid particles. The liver offers the most suitable conditions for this, and in every case careful search will show the presence of a few tubercles in this organ. In some cases the bacilli may apparently gain access to the blood without producing any other lesions. From the primary infection they may in some way gain entrance into the blood and be deposited in various organs. In no other way are we able to explain the primary tuberculosis of the bones and other organs into which they could have been carried only by the blood.

Of late the theory of congenital tuberculosis, the result of intra-uterine infection, has received more credence than formerly. Baumgarten particularly upholds this view, and explains in this way certain cases in which the infection is otherwise obscure. In a few cases congenital tuberculosis has been proven beyond doubt both in animals and in man. The first case in which this was shown was in the organs of a fœtal calf, and careful investigation has shown that this condition is not so very uncommon. Baumgarten found a caseous tuberculous nodule in the cervical vertebræ of a stillborn infant. Birch-Hirschfeld found tubercle bacilli in a seven months' fœtus and placenta removed by Cæsarean section from a mother affected with general miliary tuberculosis. The bacilli were demonstrated both by direct examination and by the inoculation of

guinea-pigs. Cases of tuberculosis in infants dying the first few days or weeks after birth are not so very uncommon, and many of these cases should be regarded as due to intra-uterine infection. Gärtner has found that transmission of tubercle bacilli from the mother to the fœtus is not very uncommon in mice, canary birds, and rabbits. Nor is the infrequency of tuberculosis in new-born children and infants a conclusive argument against intra-uterine infection. The infection may take place in intra-uterine life, and the disease remain latent for a number of years.

The question as to the frequency of directly inherited or congenital tuberculosis must be considered in connection with the fact, referred to above (p. 245), that the children of a tuberculous parent usually live in a house or room which is more or less infected with the specific bacilli derived from the sputa of the parent, and hence are more than usually liable to contract the disease.

GENERAL BACTERIOLOGY OF SURGICAL INFECTIONS.

By WILLIAM H. WELCH, M. D.

Members of each of the three groups of pathogenic micro-organisms —bacteria, fungi, and protozoa—may cause surgical infections. Fungi and protozoa, however, are far less commonly concerned in these infections than are bacteria. In a general consideration of the conditions of surgical infection bacteria are the organisms which require chief attention, so that the subjects to be considered in this article can be appropriately included under the designation "General Bacteriology of Surgical Infections."

The term "general bacteriology" is here used in distinction from "special bacteriology" to designate the general relations of bacteria to surgical infections. It is not deemed necessary in this article to enter into a detailed consideration of the morphological and cultural characters of bacteria. This subject is fully treated in works especially devoted to bacteriology.

Infectious diseases which require especial consideration by the surgeon include, on the one hand, many specific infections, such as tuberculosis, tetanus, glanders, anthrax, and actinomycosis, and, on the other hand, traumatic and other inflammatory and septic infections caused by various widely-distributed bacterial species.

The specific infectious diseases, such as tuberculosis, tetanus, etc., are for the most part sharply differentiated by their anatomical and clinical characters, and are caused by micro-organisms which are constantly and exclusively associated with their respective diseases.

On the other hand, the common traumatic infections and other surgical inflammations and septic processes do not present equally sharp and definite differential characters, and apparently identical or similar pathological processes belonging to this group of affections may be caused by various micro-organisms. Thus we do not find in such diseases as septicæmia, pyæmia, abscesses, osteomyelitis, puerperal fever, or other septic and localized inflammations, or, in general, in the infections of wounds, any single bacterial species constantly and exclusively associated with each of these affections, but each disease of this group may be caused by more than one species of micro-organism.

The etiology of these common septic and inflammatory affections presents for our consideration many problems quite distinct from those pertaining to the causation of the specific infections. The views now held as regards sources of infection, operative procedures, and the management of wounds have been developed largely as the result of investigations concerning the relation of bacteria to traumatic infections.

It is important that the surgeon should become familiar with the various kinds of bacteria concerned in surgical infections, with their distribution on exposed surfaces of the body and in the outer world, with the ways by which they may enter and be discharged from the body, with the various conditions which favor their invasion and multiplication in the body, with their pathogenic manifestations, and with the means of combating them. It is proposed in this article to present the more important considerations pertaining to these subjects so far as they do not fall more appropriately for their treatment to other sections of this work.

We shall consider first the distribution of bacteria on exposed surfaces of the body, having especially in view its surgical bearings. Knowledge of the distribution of pathogenic bacteria is of importance in the study of the causation of surgical infections, as indeed of all infectious diseases.

Bacteria of the Skin.

There are various questions of surgical interest relating to the bacteria of the skin. The destruction of the surface bacteria both on the hands of the operator and his assistants and over the field of operation in the patient is of fundamental importance in surgical technique. It is important to determine the possibilities of danger from infection by bacteria commonly or occasionally found in or on the skin. Ignorance of the bacterial flora of the normal skin has led some investigators to erroneous interpretations of their observations as to the source of bacteria found in wounds treated aseptically or antiseptically, and as to the presence of supposed specific pathogenic bacteria in certain cutaneous diseases.

The micro-organisms of the human skin have been studied by several investigators, of whom may be mentioned Bizzozero, Bordoni-Uffreduzzi, Unna, Maggiora, Mittmann, Fürbringer, Preindlsberger, Robb and Ghriskey, and Welch.[1]

As the skin is exposed to contamination from the air and all sorts of sources, it is evident that there is scarcely any limit to the number of species of bacteria which may possibly be found on the skin. Most investigators of this subject have not had the patience or have not thought it worth while to attempt to identify or to describe all of the various kinds of bacteria developing in cultures from the surface of the skin. Mittmann mentions seventy-eight different species of cutaneous bacteria, of which fifty-six were cocci. His descriptions, however, are so imperfect as scarcely to serve for the identification of the species. Preindlsberger describes thirty-two species, of which twenty-eight were cocci. Maggiora isolated twenty-nine micro-organisms, of which twenty-two were bacteria, three budding fungi, and four moulds. Most of these bacteria are such

[1] Bizzozero, *Virchow's Archiv*, Bd. 98; Bordoni-Uffreduzzi, *Fortschritte der Medicin*, 1886, p. 151; Unna, *Monatshefte für praktische Dermatologie*, 1889, 1890, 1891; Maggiora, *Giornale della R. Società d'Igiene*, 1889; Mittmann, *Virchow's Archiv*, Bd. 113; Fürbringer, *Desinfektion d. Hände d. Arztes*, Wiesbaden, 1888; Preindlsberger, *Zur Kenntniss der Bacterien des Unternagelraumes u. s. w.*, Wien, 1891; Robb and Ghriskey, *Johns Hopkins Hospital Bulletin*, April, 1892; Welch, *Trans. of the Congr. of American Physicians and Surgeons*, vol. ii., and *Maryland Medical Journal*, Nov. 14, 1891.

as are often found in the air or on external objects. Cocci are usually found much more abundantly than bacilli in cultures from the skin.

Great variations exist in different cases as to the kinds and the number of bacteria found on the skin. Sometimes one species predominates over the rest, indicating that it has multiplied and overgrown other bacteria. The conditions in general are not favorable for the growth of bacteria on the surface of the skin, but under the nails and in situations where moisture collects, as in the axillæ, the groins, and between the toes, there may be abundant multiplication of certain species of micro-organisms. Although bacteria predominate, budding and mould fungi are often present. The large number of micro-organisms which accumulate beneath the nails is a matter of surgical importance. From a minute particle of material from this situation sometimes as many as two thousand to five thousand colonies develop in culture media, although usually the number is much less, and may be very small indeed, perhaps not more than three or four colonies.

The writer in 1891 was the first to call attention to the fact that, although in general the bacterial flora of the skin is inconstant and indefinite in its special characters, there is one bacterial species, to which he gave the name of *staphylococcus epidermidis albus*, which is found with such regularity in cultures from the skin that it may properly be regarded as a regular inhabitant of the normal skin, just as the bacillus coli communis is a regular inhabitant of the intestinal canal. The principal data relating to this staphylococcus were established by the researches of Robb and Ghriskey. We consider this coccus to be a variety of the staphylococcus pyogenes albus. It is possessed of feeble pyogenic power, and usually liquefies gelatin and coagulates milk more slowly than the ordinary white pyogenic staphylococcus. For these reasons, but especially to emphasize the epidermis as a normal habitat for this organism, we applied the designation mentioned.

One of the chief points of interest relating to this coccus is that it is very often, probably regularly, present in layers of epidermis along the hair-shafts, deeper than can be reached by any known means of cutaneous disinfection save the application of heat. After complete sterilization of the surface of the skin, so that scrapings are sterile when inoculated into culture media, the presence of this white coccus can still be demonstrated by making cultures from sutures passed through the skin or from excised pieces of skin.

The staphylococcus epidermidis albus is usually innocuous. It is found frequently in aseptic wounds of the skin without causing suppuration or any trouble. The source of this coccus in aseptic wounds does not seem to be known to many who have made bacteriological examinations of such wounds; thus Büdinger,[1] who examined in 1892 twenty operative wounds which healed by first intention in Billroth's clinic, could not suggest any other origin for its presence than the air, and C. Fraenkel[2] suggests that it is brought to the wound by the blood-current—suggestions which were rendered quite unnecessary by our previous researches.

Although this white epidermal staphylococcus is often found in wounds without any disturbance in the process of healing, it may be

[1] Büdinger, *Wiener klin. Wochenschr.*, 1892, Nos. 22, 24, 25.
[2] C. Fraenkel, *Baumgarten's Jahresbericht*, 1892, p. 28.

the cause of some disturbance, characterized especially by elevation of temperature and moderate suppuration. This is particularly likely to be the case when there is necrotic or strangulated tissue in the wound or when foreign bodies have been introduced into the wound. It is a common, although not the sole, cause of stitch-abscesses, and it is prone to travel down along the sides of a drainage-tube, and under these circumstances may cause the wound to suppurate. It is often associated with other pyogenic cocci in cutaneous inflammations. We can now understand how, without any flaw in the antiseptic technique of the surgeon, this micro-organism may be present in wounds, and we have a satisfactory explanation of the frequent occurrence of stitch-abscesses.

This white skin-coccus is often present in cultures from blood obtained by puncture of the human skin and in cultures from the sweat after complete disinfection of the surface of the skin. Some observers seem to have supposed that when the staphylococcus albus is demonstrated under these conditions its presence in the circulating blood or its excretion by the sweat-glands can be inferred. But it is evident that such an inference is unwarranted without additional proof.

There are various other white cocci, and also several species of yellow cocci, both liquefying and non-liquefying, which are frequently found in cultures from the skin. Some of the yellow cocci can readily be mistaken for the staphylococcus pyogenes aureus, unless they are carefully studied in culture media. The staphylococcus pyogenes aureus may be found on the skin, as will be mentioned presently.

The kinds and the number of bacteria found upon exposed parts of the skin vary considerably according to the habits and the occupation of the individual. Of especial interest in this connection are the results of the examination of the skin of surgeons and others who come into contact with infected persons either during life or at the autopsy-table. We have found only exceptionally the *staphylococcus pyogenes aureus* upon the hands of those who do not come into proximity to surgical or infected cases, whereas we have many times found this micro-organism upon the hands of surgeons, their assistants, and surgical nurses. In examining the hands of those who use corrosive sublimate as a disinfectant it is necessary first to neutralize the sublimate with ammonium sulphide, as we have found that the sublimate may prevent the development of cutaneous micro-organisms with which it has come into contact, although it has not killed them; and this restraining influence may be manifest days, and even weeks, after the application of the sublimate.

The length of time that the yellow pyogenic staphylococcus may persist upon the hands varies, and doubtless largely, according to the methods and extent of cleansing the skin. It certainly may persist for several days, although it may disappear in a few hours. It does not seem usually to grow down, as does the white epidermal coccus, into the deeper layers of the skin, so that ordinary methods of disinfection of the skin are likely to remove or destroy this organism. By rubbing or by the application of pressure the staphylococcus aureus may, however, be pressed into the deeper layers, particularly into the hair-follicles, and there cause furuncles, as has been shown by the experiments of Garré, Schimmelbusch, Wasmuth, and others. The view which has been advocated by some writers that it requires more thorough disinfection to

remove or destroy pathogenic bacteria accidentally or intentionally applied to the skin than to kill the ordinary bacteria of the skin is not supported by experiments. The healthy skin in general is not a favorable resting- or breeding-place to secure the long persistence of pathogenic bacteria, with the exception of the white epidermal coccus, which possesses relatively little pathogenic power under ordinary circumstances.

The *streptococcus pyogenes* has been found less frequently than the staphylococcus aureus in cultures from the skin, and here too chiefly in cultures from the skin of infected patients or of those who have been in proximity to them. It is well to bear in mind that these pyogenic cocci are not necessarily limited to the immediate neighborhood of an infected wound or focus, but may occur on other parts of the body, as well as in the air or on objects which have been near the patient. Thus Preindlsberger found the aureus in the dirt beneath the finger-nails of a patient with fracture of the femur, and the streptococcus pyogenes in the same situation in a patient with osteomyelitis femoris for which necrotomy had been performed. The complete disinfection of an infected wound, even if that were possible, would not therefore furnish a guarantee that pyogenic cocci were not present upon the surface of the patient's body in other situations.

The *bacillus pyocyaneus* is a common parasite upon the human skin. Mühsam[1] found it in the axilla and in the anal and inguinal folds of healthy persons in 50 per cent. of the cases examined. Probably local conditions were concerned in these observations, as others have not found this organism upon the healthy skin with such frequency. Although this organism may manifest important pathogenic activities, its presence in wounds is usually made evident chiefly by the green or blue discoloration of the dressings. It was formerly supposed to enter the wound from the air, but it doubtless is often derived also from the skin of the patient.

The common intestinal bacterium, the *bacillus coli communis*, is of course often present on the skin about the anus. In abscesses in this situation it is often found either alone or associated with other bacteria. The colon bacillus may also be found upon the skin in other parts of the body. It is a widely-distributed bacterium outside of the animal body. It has repeatedly been found in wounds in different parts of the body.

Skin contaminated with the soil, which, as is well known, contains in many situations abundant bacilli of tetanus and of malignant œdema, is likely to present these micro-organisms. This contamination relates, of course, especially to the hands, and in the case of those who go barefoot or have holes in their shoes also to the feet. Maggiora was able to demonstrate the bacillus of malignant œdema in scrapings from between the toes of a person who had walked for half an hour in a garden with a torn shoe. It is not therefore in all cases necessary to suppose that the tetanus bacillus enters a wound from the object which causes the wound, for this bacillus may previously have been attached to the skin. It may in this connection be mentioned that the fæces of herbivorous animals often contain the tetanus bacillus, and in a condition more

[1] Mühsam, cited by Schimmelbusch, *Samml. klinischer Vorträge von Volkmann*, Serie 3, Heft. ii. No. 62.

likely to produce tetanus than when the bacillus is obtained from the soil. Buday[1] has reported a case of tetanus fatal in twenty-four hours which followed the smearing of a wound with fæces.

The *smegma bacillus* may be considered in connection with the cutaneous bacteria. This bacterium is usually present in the smegma, and may be found about the penis, scrotum, vulva, and anus. Attention was first called to this bacillus by Alvarez and Tavel and by Matterstock in 1885, on account of its resemblance in morphology and staining reactions to Lustgarten's bacillus, which at that time was thought by its discoverer to be the specific cause of syphilis. Greater practical importance, however, belongs to the smegma bacillus at present on account of the possibility of mistaking it from its staining properties for the tubercle bacillus, and there is reason to believe that such mistakes have been made in examinations of the urine and of secretions or exudates about the external genitals and the anus. The smegma bacillus resembles the tubercle bacillus in the property of retaining the staining dye after such application of acids and alcohol that all known bacteria except the tubercle bacillus, the smegma bacillus, and the leprosy bacillus are decolorized. This property probably does not inhere in the smegma bacilli as such, but is due to the presence of chemical constituents of the smegma, although this point is not positively settled. In the opinion of the writer this peculiar staining reaction does not belong to only a single species of bacillus in the smegma, but to several, so that it is more proper to speak of smegma bacilli with this reaction. Mistakes are particularly likely to occur when the handy and popular Gabbet's stain for the tubercle bacillus is employed. The usual statement is that the smegma bacilli can be distinguished from the tubercle bacillus by less resistance to decolorizing agents, particularly to nitric acid, hydrochloric acid, and alcohol, also to counter-stains; and this often holds true. Nevertheless, smegma bacilli are sometimes encountered which are as resistant to these decolorizers as are tubercle bacilli. Especial attention should be given to the morphological appearances, as the size and shape of the bacilli often suffice for the distinction, although there is considerable diversity as regards this feature between the different smegma bacilli which resist decolorization. Although smegma bacilli may be present with pathogenic bacteria in lesions around the genitals and anus, they are not known to possess pathogenic capacity.

Many bacteria are attached to the hairs of the body, and particles containing bacteria may readily be detached from the hair. Robb has studied the bacteria which fall off from the hair of the head by movement or by combing the hair. They are identical with those found on the skin, as might be expected. Haegler has cultivated pyogenic staphylococci from the hair of surgeons, and calls attention to the possibility of such cocci falling from the hair into a wound or upon objects coming into contact with the wound during an operation. Wright has found the diphtheria bacillus on the hair of nurses in attendance on cases of diphtheria.

The cerumen is rich in bacteria. Rohrer[2] isolated sixteen species of micro-organisms from the cerumen of fifty cases, but he has not attempted

[1] Buday, *Pester Med.-chir. Presse*, 1894, No. 19.
[2] Rohrer, *Archiv f. Ohrenheilk.*, Bd. xxix.

to identify any of these with previously-known bacteria, and his statements as to the existence of pathogenic bacteria in the cerumen are not based upon conclusive observations.

Bacteria of Exposed Mucous Surfaces.

The way is open for the access of micro-organisms to mucous membranes which cover parts which communicate with the outer world through the external orifices of the body. So far as temperature, moisture, and the presence of nutritive pabulum are concerned, the conditions are manifestly more favorable for the growth of bacteria upon mucous surfaces than upon the dry skin. These relatively favorable conditions for the development of micro-organisms upon mucous membranes are, however, counteracted in large measure by various mechanical and chemical influences which prevent the prolonged survival of most of the bacteria which may enter through the external orifices of the body. There are, however, many bacteria which may multiply, or persist for a long time or indefinitely, upon certain mucous membranes in health, particularly those of the alimentary canal and of the upper respiratory tract, and there are some bacterial species which find their natural home here. Some pathogenic bacteria may live upon certain mucous membranes without doing harm.

The study of the bacterial flora of exposed mucous membranes in health and in disease has brought to light many points of surgical interest.

Conjunctiva.—The bacteriology of the conjunctiva has been investigated by many ophthalmologists, of whom may be especially mentioned Fick, Weeks, Leber, Felser, van Genderen Stort, Gombert, Bernheim, Hildebrandt, Franke, Marthen, and Bach.[1]

When one considers the exposed situation of the conjunctiva, it is surprising to find how small is the number of bacteria usually present in the conjunctival sac. Fick found, by microscopical examination of fifty healthy conjunctivæ, bacteria in only eighteen, although in another series in which forty-nine healthy eyes of paupers were examined bacteria were missed in only six. A negative microscopical examination, however, indicates only that the number of bacteria is small, as then their presence may readily be overlooked without the aid of cultures. As a matter of fact, cultures from the healthy conjunctival sac usually furnish colonies of bacteria. Their number may be considerable, but it often happens that not more than three or four colonies develop from a loopful of fluid from the conjunctiva, and it is not very uncommon for culture media inoculated in this way to remain sterile. It is to be assumed that the conjunctival sac ordinarily contains bacteria. The secretion within the lachrymal glands is sterile.

Bach describes twenty-six species of bacteria isolated in pure culture from the healthy or diseased conjunctiva. Of these, ten are liquefying cocci, nine non-liquefying cocci, five liquefying bacilli, one non-liquefying bacillus, and one cladothrix. Ten of the twenty-six bacteria were found to be more or less pathogenic when inoculated into the rabbit's cornea.

[1] L. Bach, "Ueb. d. Keimgehalt des Bindehautsackes," *Archiv f. Ophthalmologie*, Bd. xl. p. 130. This article contains the references to the other articles cited in the text.

Pink yeast and mould fungi have also been cultivated from the conjunctiva.

Bach considers that of these various bacteria only the staphylococcus pyogenes aureus and albus and the streptococcus pyogenes are demonstrated to be pathogenic for man, although the possibility that others in the list may be pathogenic for man must be admitted. In a few instances the staphylococcus pyogenes aureus, and in more the albus, have been cultivated from the healthy conjunctiva. Cultures of the staphylococcus pyogenes aureus have been introduced into the healthy conjunctival sac of man and animals without causing inflammation.

Inasmuch as many micro-organisms must enter the conjunctival sac from the air, the edges of the eyelids, and from contact with the fingers and other objects, and as relatively few bacteria are found ordinarily in cultures from this part, it is evident that there must be some very efficient mechanism which rids the conjunctiva of most of the bacteria which enter. There are two principal agencies by which this may be accomplished—namely, mechanical removal through the naso-lachrymal duct, and the germicidal action of the lachrymal and conjunctival secretions. Some investigators have attached the greater importance to the former, others to the latter, of these agencies. Experiments have shown that each may be operative, but the mechanical removal has been shown to be especially efficient and prompt in its action.

Van Genderen Stort has made experiments upon rabbits, and Bach upon man, by dropping pure liquid cultures of easily-identified bacteria, such as the Kielwater bacillus, the bacillus coli communis, the staphylococcus aureus, into the conjunctival sac, and then determining by cultures the length of time during which they can be demonstrated. Van Genderen Stort found after fifteen minutes the inoculated bacteria reduced to a small number, and at the end of an hour they had nearly or entirely disappeared from the conjunctival sac. Cultures from the nose showed that they had been carried down the naso-lachrymal duct, and that after five minutes they were abundant in the cultures from the nasal cavity. Identical results were obtained by Bach in his experiments on human beings. In the experiment of Bach with the staphylococcus aureus, however, which was introduced in such number that the immediate plates from the conjunctiva contained countless colonies, there were still seventy-four colonies in the plates made after twenty-four hours.

The same experiments were made after ligation of the naso-lachrymal duct. Under these circumstances the inoculated bacteria also disappeared from the conjunctival sac, but more slowly than when the duct was open. Still, after an hour most of the bacteria had been removed. It was found that they had been carried away by the lachrymal secretion which flowed over the eyelids. If the eyelids were closed by a bandage, the bacteria, with open nasal duct, rapidly passed down into the nose, and they did not appear to pass out between the closed eyelids. When, however, the duct was closed, they appeared abundantly in the bandage.

Bernheim has demonstrated that the tears possess considerable bactericidal power over certain species of bacteria, and his results have been in part confirmed by the experiments of Marthen, Bach, and others. The staphylococcus pyogenes aureus is killed in moderate number, and the typhoid bacillus in larger number, by the lachrymal secretion. We

must therefore assign importance to this chemical action, as well as to the mechanical removal, in ridding the conjunctiva of invading bacteria. Neither of these agencies suffices to remove all of the bacteria. Some bacteria grow readily in the fluid of the conjunctiva. As has already been mentioned, the conjuctiva nearly always contains some bacteria. The orifices of the Meibomian glands, the cilia, and the edges of the eyelids usually contain many bacteria, and these of course may readily enter the conjunctival sac.

Bach was unable to demonstrate that bacteria introduced into the nasal cavity ever make their way up the nasal duct to the eye.

It is difficult to obtain complete disinfection of the conjunctival sac. The number of bacteria may be greatly reduced, either by the application of antiseptics or by simple mechanical cleansing, combined with irrigation by an indifferent fluid, such as sterilized salt-solution. Bach obtained the best results by the latter procedure, by which in sixteen out of forty-two cases he rendered the conjunctiva sterile.

The importance of familiarity with the saprophytes to be found on exposed mucous membranes is illustrated by the history of the so-called xerosis bacillus. This bacillus was discovered by Neisser in 1882 in xerosis of the conjunctiva, and was regarded by him as the cause of this disease. This conclusion was adopted by several subsequent investigators, who found this bacillus constantly present in xerophthalmia. This same bacillus has, however, been demonstrated by Schreiber, working under Neisser's direction, in various other affections of the eye, and also, although in small number, in the normal conjunctival sac. Neisser has therefore given his assent to the conclusion expressed by Schreiber:[1] "The so-called xerosis bacilli are to be regarded as saprophytes which are often present in the conjunctiva and its secretion, both in diseased and healthy eyes, and they play no special rôle either in xerosis or in other diseases of the eye."

The xerosis bacillus belongs to an interesting group of bacteria which are characterized by remarkable irregularities in size and shape—so-called involution forms—and by irregularities in staining, especially by the presence of deeply-staining isolated granules. It is not positively proven to form spores, although some of the isolated granules are interpreted as such by Ernst and by Neisser. To this same group belong the diphtheria bacillus of Löffler and the so-called pseudo-diphtheria bacilli.

Mouth and Pharynx.[2]—All of the micro-organisms which may be present in the air, food, and ingested fluids may appear temporarily in the mouth. The number of bacteria which have been cultivated from the human mouth is very large. Miller has isolated over one hundred species. Freund has cultivated eighteen different chromogenic micro-organisms from the mouth.

It is important to distinguish between the countless bacteria which may appear as transient visitors in the mouth and those which find their permanent home there. A remarkable peculiarity of the constant inhabit-

[1] Schreiber, *Fortschritte der Medicin*, 1888, p. 656.

[2] Miller, *Die Mikro-organismen der Mundhöhle*, Leipzig, 1889; David, *Les Microbes de la Bouche*, Paris, 1890. These valuable works present the most important results hitherto obtained by the investigators of the micro-organisms of the mouth.

ants of the saliva is that most of them will not grow in our artificial culture media. This produces often a striking discrepancy between the results of microscopical examination of the buccal secretions and those obtained by cultures. Cover-slip specimens may show an enormous number of bacteria, when cultures made from the same material may show very few or even no colonies.

Miller enumerates the following as the constant buccal bacteria: *leptothrix buccalis innominata, bacillus buccalis maximus, leptothrix buccalis maxima, iodococcus vaginatus, spirillum sputigenum, spirochæte dentium.* None of these have been artificially cultivated. Bacillus buccalis maximus and iodococcus vaginatus are stained violet by iodine solution. These bacteria are often present, with others, in carious teeth, in abscesses communicating with the mouth and pharynx, and in exudates on the mucous membranes of these parts, but they have not been proven to be pathogenic.

The frequent presence of pathogenic bacteria in the healthy mouth is of great practical importance. The following pathogenic bacteria have been found repeatedly in this situation: *micrococcus lanceolatus, streptococcus pyogenes, staphylococcus pyogenes aureus* and *albus, micrococcus tetragenus, bacillus pneumoniæ* of Friedländer, *bacillus crassus sputigenus* of Kreibohm, *bacillus coli communis.* Biondi, Miller, Kreibohm, Galippe, and others have found in the mouth additional pathogenic bacteria in isolated cases, mostly, however, with some morbid condition.

The micrococcus lanceolatus was discovered by Sternberg in his saliva in 1880. Many names have been given to this bacterium, the more common synonyms being diplococcus pneumoniæ, pneumococcus of Fraenkel and Weichselbaum, diplococcus lanceolatus, micrococcus of sputum septicæmia, and micrococcus pneumoniæ cruposæ (Sternberg). This micro-organism was found by Netter in a virulent condition in 15 to 20 per cent., of the healthy persons whom he examined. It varies markedly in virulence, and it is probably present in a non-virulent condition in many cases. Indeed, Kruse and Pansini believe that the micrococcus lanceolatus is a regular inhabitant of the human mouth, although it is present in a virulent state in only about one out of five or six persons. As the lanceolate coccus, especially when its virulence is weak or absent, may grow in chains and present cultural characters of the streptococcus pyogenes, it is often difficult, if not impossible, to distinguish between these bacteria.

The chief interest attaching to the frequent presence of the micrococcus lanceolatus in the healthy mouth is that this bacterium is the cause of lobar pneumonia and of many cases of broncho-pneumonia. It may also be concerned in local inflammations of the throat, and as a primary or secondary invader may cause serositis and localized inflammations in various parts of the body; but the streptococcus pyogenes is a more common cause of these lesions.

Various virulent and non-virulent streptococci have been found in the mouth, both short-chained streptococci and long-chained forms, corresponding to the two varieties, streptococcus brevis and streptococcus longus. The distinctions upon which these varieties were established by Von Lingelsheim are often inconstant, and do not serve for a sharp differentiation. The chief interest belongs to the presence in the mouth

and pharynx of the streptococcus pyogenes. Netter found the streptococcus pyogenes in seven out of one hundred and twenty-seven healthy mouths examined; that is, in 5.5 per cent. of the cases. Dörnberger found streptococci in the mouths of healthy children in 45 per cent. of the ninety-four cases examined. Widal and Besançon found streptococci constantly and in large number in the mouths of twenty healthy persons, and still more abundantly in the mouth and pharynx of forty-nine persons affected with various diseases.

It often requires a painstaking examination to detect this streptococcus. The colonies are minute and pale gray, and in a plate crowded with other more striking colonies the former may escape recognition unless especial attention is given to them. If the secretions of the healthy mouth and throat be carefully examined both by cover-slip preparations and by agar plate-cultures, streptococci will be found with great frequency, if not regularly, although, as already mentioned, it is by no means easy to distinguish some of the streptococci from chain forms of the micrococcus lanceolatus.

The number of streptococci is increased and their detection is much easier in most inflammatory conditions of the tonsils and pharynx. They are commonly associated with the diphtheria bacillus in diphtheria, and they are capable of causing all grades of tonsillitis and pharyngitis, from slight erythematous forms to pseudo-membranous and necrotic inflammations.

Streptococci cultivated from the healthy mouth usually have little or no virulence as tested upon animals, and the same is often true of streptococci cultivated from the throat in various infections, local and general, although in these cases they are more likely to be pathogenic for animals.

The streptococcus pyogenes is a common and dangerous invader of the deeper air-passages and lungs and of the internal parts of the body. The portal of entry is often the tonsils and throat, and predisposing causes are inflammations and other lesions of these parts, particularly when combined with other infectious diseases and constitutional disturbances. Under conditions little understood the mouth-streptococci may acquire enhanced virulence.

The influence of predisposing causes as a factor in the etiology of infections is well exemplified by the fact that healthy mucous membranes harbor very frequently such pathogenic germs as the micrococcus lanceolatus and the streptococcus pyogenes. These bacteria often, moreover, cause no serious disturbance in the repair of wounds and injuries involving the mouth and naso-pharynx, although they must gain access to such wounds. They are, however, a standing menace in surgical operations involving these parts, and they may seriously interfere with the healing of such wounds, or may under these circumstances set up pneumonia and general infection.

Staphylococci are found often in the healthy mouth and the throat, but the genuine pyogenic staphylococci do not appear to be present with great frequency. Vignal, Netter, and Miller met the staphylococcus pyogenes aureus only in a comparatively small number of cases in their bacteriological examinations of the healthy mouth. It is found more frequently in various inflammations of the mucous membranes of this

region, but it plays no such important rôle in these as does the streptococcus pyogenes.

White liquefying cocci, often described as the staphylococcus pyogenes albus, are found oftener than the staphylococcus aureus in the mouth and throat. Some of these have been shown to possess pyogenic power, and may be accepted as the staphylococcus pyogenes albus, but others are devoid of such power.

According to the statements of Biondi, Miller, and others, the micrococcus tetragenus, which was discovered by Koch and Gaffky in a phthisical cavity, is often present in the mouth. In a considerable number of cases examined by the writer it was absent. The frequency with which certain bacteria are present in the mouth probably varies considerably in different regions and according to the class of cases selected for examination. There are various species of tetragenous cocci. The pathogenic form of Koch and Gaffky is designated by Boutron as micrococcus tetragenus septicus. This organism is present more frequently in abscesses in the neighborhood of the mouth and throat, particularly those connected with carious teeth, than in abscesses in other parts of the body, although even in the former it is rarely present.

The virulent diphtheria bacillus was found by Park and Beebe[1] in the healthy throats of eight out of three hundred and thirty persons in New York who gave no history of direct contact with cases of diphtheria. Only two of these eight persons afterward developed diphtheria. They found non-virulent, but otherwise characteristic, diphtheria bacilli in twenty-four throats of the same group of persons, and pseudo-diphtheria bacilli in twenty-seven.

The pseudo-diphtheria bacillus which is occasionally found in the throat is devoid of virulence, and presents certain cultural peculiarities distinguishing it from the genuine diphtheria bacillus. It is not known to be pathogenic. There is much confusion in the use of the term "pseudo-diphtheria bacillus," and some writers have described under this name the genuine diphtheria bacillus devoid of virulence. There is probably more than one bacterial species which may be called pseudo-diphtherial bacillus.

The mouth and adjacent parts are the most frequent portals of entry of the bacterium of actinomycosis. This organism is likely to lodge near carious teeth.

Although the mouth and throat offer more favorable conditions for the prolonged existence of many micro-organisms than do other exposed mucous membrane, nevertheless of the vast hordes of micro-organisms which must gain access to the mouth only a small number actually persist there. The conditions are evidently unfavorable for the survival of the majority of bacterial species in this situation. Those which are unable to gain a foothold must sooner or later pass down into the stomach or intestine or out through the mouth and nose or perish within the body.

The secretions in the mouth and throat, like most of the fluids of the body, possess some degree of germicidal power. Sanarelli[2] found that the saliva is capable of killing in a short time a moderate number of

[1] Welch, "Bacteriological Investigations of Diphtheria in the United States," *Am. Journ. of the Med. Sciences*, Oct., 1894.

[2] Sanarelli, *Centralbl. f. Bakter.*, 1891, Bd. x.

several pathogenic bacterial species. This was found to be the case with the staphylococcus aureus, the streptococcus pyogenes, the micrococcus tetragenus, the typhoid bacillus, and the cholera spirillum. The diphtheria bacillus, however, survived for twenty-eight to forty days, and the micrococcus lanceolatus grew well in saliva, although with rapid loss of virulence.

E. Grawitz and Steffen[1] have confirmed this observation of Sanarelli as regards the pneumococcus, and have found that the virulence of this organism may be restored by cultivating it upon pneumonic sputum prepared as an artificial culture medium. They interpret this as indicating that the virulence of the pneumococcus may be enhanced by certain chemical changes in the composition of the sputum.

There is reason to believe that the virulence of pathogenic bacteria in the mouth, notably of the micrococcus lanceolatus and the streptococcus pyogenes, may fluctuate, both in the direction of attenuation and of exaltation, but we are not acquainted with the conditions which control these changes.

The salivary glands and ducts are free from bacteria, except near the orifice of the ducts.

Respiratory Passages and Middle Ear.—In normal respiration the bacteria contained in the inspired air must enter the nasal cavities. The anatomical arrangement of the nasal passages renders these an important filtering apparatus for the protection of the deeper air-passages. It has been shown by experiments of Wright that with a respiration of one litre of air per minute from three-fourths to four-fifths of the bacteria of the inspired air are retained in the nasal cavities and their adnexa.

It has already been mentioned that most of the bacteria which enter the conjunctival sac are carried into the nose through the nasal duct. We should therefore expect that the nasal cavities would contain abundant micro-organisms.

The bacteria of the healthy nose have been studied by E. Fraenkel, Loewenberg, Hajek, von Besser, Wright, Paulsen, Weibel, Deletti, and others, with much divergence in their results. Some have found few, others many, bacteria in the nose; some have met frequently pathogenic bacteria, others rarely or not at all.

Von Besser[2] describes twelve non-pathogenic species isolated from the noses of thirty persons at work in the laboratory. In the same group of cases he found in the nose the micrococcus lanceolatus six times, the streptococcus pyogenes five times, the staphylococcus pyogenes aureus seven times. In the nasal cavities of twenty-eight convalescent hospital patients he found the micrococcus lanceolatus four times, and the streptococcus pyogenes, the staphylococcus pyogenes aureus, and the bacillus of Friedländer each once; in twenty-three soldiers and servants, the micrococcus lanceolatus four times, the staphylococcus pyogenes aureus six times, the streptococcus pyogenes once, and the Friedländer bacillus once.

Wright[3] isolated from the nasal secretion of ten healthy persons the

[1] Grawitz and Steffen, *Berliner klin. Wochenschr.*, 1894, No. 18.
[2] Von Besser, *Ziegler's Beiträge*, Bd. vi.
[3] Wright, *New York Med. Journ.*, July 27, 1889.

staphylococcus pyogenes albus six times, the aureus and citreus three times, the bacillus lactis aërogenes once, and the micrococcus tetragenus once.

Paulsen[1] made sixty-four cultures from the healthy noses of twenty-seven persons. Eleven of these were sterile, nineteen gave ten colonies or less, sixteen gave up to one hundred colonies, twelve several hundred colonies, and six furnished countless colonies. Cocci were found much oftener than bacilli. Only once did he find the streptococcus pyogenes. Pathogenic bacteria were not observed in any other of the normal cases. Upon cover-slip preparations he noted spirilla, and Weibel has cultivated a comma bacillus from the nose.

Special interest attaches to the presence of capsulated bacilli in the nose, as these are found with great frequency, if not constantly, in ozæna. The ozæna bacillus of Abel[2] resembles closely the Friedländer bacillus, but is believed by him not to be identical with it. Whether or not this bacillus is ever found in the healthy nose is not established. The Friedländer bacillus and the lanceolate coccus have repeatedly been found in the nose, especially in inflammatory conditions. The rhinoscleroma bacillus is a capsulated bacillus much like the Friedländer bacillus, but differing from it by staining with Gram's method. We do not at present possess an entirely satisfactory differentiation of a group of capsulated bacilli to which Friedländer's bacillus, the ozæna bacillus, the rhinoscleroma bacillus, the capsulated bacillus of Pfeiffer, and some others belong.

The diphtheria bacillus is constantly found in fibrinous rhinitis. Various bacteria, especially diplococci, have been found in the secretion of coryza. When this secretion is abundantly poured out, it often happens that cultures from several drops of it contain very few colonies or are sterile.

Straus has recently made the important observation that the tubercle bacillus is often present in the nasal cavities of healthy persons who spend much of their time in proximity to tuberculous patients. He examined for tubercle bacilli the contents of the nasal cavities of those engaged about hospital wards containing consumptives. Twenty-nine such examinations were made by the inoculation of guinea-pigs. In nine cases the guinea-pig developed tuberculosis. Of these nine persons, six were healthy attendants occupied in such work as sweeping the floor and shaking bed-linen, one was a patient with a chronic non-tuberculous ailment, and two were medical students who spent several hours daily in the hospital. None of these individuals presented the slightest evidence of tuberculosis. These observations are even more significant than those of Cornet as to the abundance and wide distribution of tubercle bacilli in the neighborhood of consumptives.

Wurtz and Lermoyez have found that the nasal mucus possesses considerable bactericidal capacity.

Von Besser found bacteria abundantly in the larynx and bronchi of human corpses, but he demonstrated that after death the fluids from the mouth and naso-pharynx may readily penetrate even into the smaller bronchi, and moreover in his cases the lungs and air-passages were dis-

[1] Paulsen, *Centralbl. f. Bakter.*, Bd. viii. p. 344.
[2] Abel, *ibid.*, Bd. xiii. p. 161.

eased; so that he attaches no importance to his observations as bearing upon the question of the presence of bacteria in these parts in health.

Hildebrandt[1] found that culture media inoculated with bits of the lung and of tracheal mucus from recently-killed rabbits usually remained sterile, and he concludes that practically all bacteria which enter with the air are retained in the upper air-passages and do not penetrate below the larynx. This protection, however, has its limits, as when the inspired air was loaded with fungus-spores these could be demonstrated after half an hour in the lungs. That foreign particles in the air may be conveyed into the lungs is evidenced by the coal particles regularly found in the lungs.

Wargunin, in opposition to Hildebrandt, isolated nine different kinds of bacteria from the trachea, bronchi, and lungs of recently-killed healthy animals.

The observations of the writer are in harmony with Hildebrandt's results as to the usual absence of bacteria, at least in sufficient number to be demonstrable by ordinary culture methods, in the bronchi and lungs of healthy animals.

At autopsies on human beings bacteria, including the micrococcus lanceolatus and the streptococcus pyogenes, may be found in the lungs without noticeable lesion of this organ.

The action of the ciliated epithelium and coughing would tend to drive out bacteria which may have entered the trachea and bronchi.

The expired air is free from micro-organisms, except as these may be mechanically detached, as in sneezing or coughing.

We are not informed as to the frequency with which bacteria are present in the healthy tympanic cavity. That bacteria may pass up the Eustachian tube into the middle ear is shown by the presence in otitis media of various micro-organisms often found in the mouth and naso-pharynx, notably the micrococcus lanceolatus, the streptococcus pyogenes, the Friedländer bacillus, and the pyogenic staphylococci. There are of course other paths by which micro-organisms may be carried into the middle ear, as the lymphatic and blood-currents, and in meningitis from the cranial cavity.

Netter found constantly in the middle ear of new-born infants, at autopsy, bacteria, and among these were pathogenic forms to which he attributes the frequent occurrence of middle-ear inflammations in infants. In autopsies upon one hundred and eight infants less than one year old H. Kossel found otitis media in eighty-five cases. The most common organism in these cases was a delicate bacillus, apparently identical with Pfeiffer's pseudo-influenza bacillus (38 cases). In addition were found the diplococcus pneumoniæ (10), streptococci (4), thick bacilli (2), staphylococci (2), and the bacillus pyocyaneus (once). One case was tuberculous otitis. Some writers are of the opinion that changes often found in the middle ear of the new-born are post-mortem alterations.

Stomach and Intestine.—The study of the micro-organisms present in the stomach and intestine presents many points of physiological and pathological interest, but we must confine our attention chiefly to those of surgical interest. When we consider the relations of intestinal bacteria to various surgical affections, such as perforative and

[1] Hildebrandt, *Ziegler's Beiträge*, Bd. ii.

other forms of peritonitis, appendicitis, and even infections remote from the intestinal canal, it is apparent that this subject claims the attention of the surgeon.

The main sources of the micro-organisms of the stomach and intestine are the ingesta and the air. From these sources countless bacteria and fungi of all kinds are introduced into the alimentary canal, but, as is true of other exposed mucous surfaces, only a limited number of species are capable of prolonged existence in this situation.

The meconium of the new-born infant is sterile, but within twenty-four hours after birth it usually contains abundant bacteria. Although many varieties of bacteria may be found, Escherich has demonstrated a constant bacterial flora in the fæces of milk-fed infants. These constantly-present intestinal bacteria are the bacillus lactis aërogenes, predominating in the small intestine, and the bacillus coli communis, predominating in the large intestine. These bacteria remain throughout life as the obligatory and characteristic intestinal bacteria of man in health, and as they are frequent secondary invaders of the body in disease, and may be concerned in various surgical and other diseases, much practical interest attaches to them.

The bacterial flora of the small intestine, particularly in its upper part, is more varied, as tested by plate cultures, than that of the large intestine. In fact, the comparison of the results of microscopical examination and of cultures from the stools indicates that a large number of the bacteria in the fæces are dead.

As there is very little free oxygen in the intestinal canal, the conditions are not favorable for the multiplication of obligatory aërobes. Most of the bacteria found in the intestine are strict anaërobes or facultative anaërobes, but anthrax spores, which require oxygen for their germination, develop into bacilli in the intestinal canal.

It is certain that pathogenic bacteria of many kinds often find their way into the intestinal canal; in fact, there is probably no pathogenic germ which may not in certain individuals and in certain times and places be present in the intestine.

It is true that the acid gastric juice may kill many of the micro-organisms which enter the stomach, but there are many which resist its action. If we were to rely exclusively upon the results of experiments in the test-tube on the germicidal action of the acid gastric juice, particularly the very acid juice of some animals, we should consider this action a formidable obstacle to the passage of living bacteria into the intestine. But when we consider the insusceptibility of many bacteria to weak acids, the relatively slight and varying acidity of the human gastric juice, the absence at times of any acid in the stomach, the withdrawal in large measure from the direct and concentrated action of the gastric juice of bacteria contained in ingested masses of food and large volumes of fluid, and the rapidity with which the gastric contents may pass into the duodenum, we can understand how micro-organisms, even those very susceptible to acids, may find frequent opportunity to enter the intestine. Only a fraction, usually not more than .05 to .1 per cent., of the total acidity of the stomach is due to free hydrochloric acid, and the proteid hydrochlorides possess very little bactericidal power.

Many organisms can grow in the human stomach even when it is very

acid, as has been shown by Gillespie.[1] The number and variety of micro-organisms which have been isolated from the human stomach by Macfadyen, Abelous, Oppler, Gillespie, and others are very great, but it would serve no useful purpose to enumerate them here. The bacillus lactis aërogenes, the bacillus coli communis, and the pyogenic cocci may be specified as having been repeatedly found in the healthy stomach.

The list of pathogenic bacteria which have been found in the intestinal contents is a long one. Many are present only accidentally and as a transient phenomenon. Some are found with such frequency as to merit special notice. In general, the conditions are not favorable for extensive multiplication of most pathogenic micro-organisms in the healthy intestine.

Pyogenic cocci are rarely absent from the intestine. They are often present in such small number as to escape detection, but the great frequency with which these cocci, particularly the streptococcus pyogenes, are found in the exudate of perforative peritonitis, where they can rapidly multiply, shows that they are common inhabitants of the intestine. Gessner found a pathogenic streptococcus, probably identical with the streptococcus pyogenes, in large numbers in the duodenum of six persons out of eighteen examined at autopsy.

The bacillus pyocyaneus and the proteus bacilli are also often present in the intestine. The tetanus bacillus and the bacillus of malignant œdema are regular inhabitants of the intestine of herbivorous animals. The micrococcus lanceolatus has been found repeatedly in the human intestine, likewise the bacillus pyogenes fœtidus. The bacillus aërogenes capsulatus has been found by the writer in the intestine in two cases of perforative peritonitis with production of gas. The occurrence of intestinal actinomycosis and of perityphlitis actinomycotica shows that the actinomyces may find its way into the intestine.

There are various other pathogenic bacteria which have been occasionally found in the intestine, but those which have been mentioned are the ones of chief surgical interest. The specific intestinal infections of typhoid fever, cholera, tuberculosis, and anthrax are not considered here. The amœba dysenteriæ, on account of its relation to abscess of the liver and lungs, deserves mention.

In this connection it may be stated that the bile in the normal bile-ducts and gall-bladder is to be regarded as free from bacteria. Under various conditions, however, the colon bacillus and other bacteria, particularly the pyogenic cocci, often wander into the biliary passages. The writer has found very frequently the colon bacillus in cultures made from the interior of gall-stones. It is not uncommon at autopsies to find the colon bacillus, less frequently pyogenic cocci, particularly streptococci, in the bile without any alteration in the bile or evident lesion to explain the migration of these bacteria.

Contrary to an old idea, the bile has not been found to possess any decided germicidal property, at least as regards most bacteria.

GENITO-URINARY TRACT.—It has been shown by Lustgarten and Mannaberg, Rovsing, Steinschneider with Galewsky, Petit and Wasser-

[1] Gillespie, "The Bacteria of the Stomach," *The Journal of Pathology and Bacteriology*, vol. i. p. 279. Here can be found references to the literature of this subject.

mann, and Hofmeister[1] that the healthy *male urethra* always contains bacteria. These are abundant and varied in the fossa navicularis, and diminish rapidly in number and kind toward the posterior part of the urethra. How far back they extend is not positively known. They were found by Hofmeister as far back as eight centimetres from the external orifice under conditions making it probable that they existed at this point, and were not simply pushed back by the sterilized glass tube which was introduced for the passage of the inoculating wire. Urethral bacteria are usually present in urine voided after sterilization of the meatus and fossa, even in the urine passed toward the end of micturition.

Lustgarten and Mannaberg by microscopical examination of the normal male urethra distinguished ten different kinds of bacteria—namely, four bacilli and six cocci. Among the bacilli was the smegma bacillus, which has already been mentioned in describing the bacteria of the skin (page 254). Among the cocci was a diplococcus which they describe as identical in form and staining reactions with the gonococcus. They isolated in cultures seven species of cocci, white and yellow. Among these cocci was found the staphylococcus pyogenes aureus. They observed that the common urethral saprophytes were incapable of causing ammoniacal fermentation of the urine, and that they died when planted in urine.

Rovsing, in opposition to most other investigators, found in the normal urethra pyogenic and non-pyogenic bacteria capable of fermenting urine and identical with many of the bacteria found in cystitis, so that he concludes that the usual source of the bacteria causing cystitis is from the urethral flora and not from the air bacteria.

Steinschneider describes four species of diplococci, identical with forms previously recognized by Lustgarten and Mannaberg, as occurring in the normal urethra. Of these, a milk-white diplococcus, which was met in 87 per cent. of the eighty-six healthy and gonorrhœal cases examined, is regarded as the most common bacterium of the urethra. Next in frequency is an orange-yellow diplococcus found in 44.2 per cent. of the cases. These two species are stained by Gram's method, and need not be confounded with the gonococcus. Steinschneider isolated from three cases a grayish-white diplococcus, and from one case a lemon-yellow diplococcus, which were decolorized by Gram's stain and which may correspond to Lustgarten's pseudo-gonococci. He concludes that in only 5 per cent. of the cases are diplococci found which are decolorized by Gram.

Petit and Wassermann, whose methods were open to objection, cultivated from the normal urethra of four persons five cocci, six bacilli, two sarcinæ, and two yeast-fungi. They did not find a pseudo-gonococcus.

Hofmeister did not find the normal urethral flora as varied as have some observers. Two species of diplococci—viz. a non-liquefying white or yellow, large coccus and a liquefying, smaller, gray coccus—he regards as regular inhabitants of the urethra. An orange-yellow and an opaque white liquefying diplococcus he isolated, each from two cases. None of these four diplococci from recent cultures were decolorized by Gram, but

[1] Hofmeister, *Fortschritte der Medicin*, 1888, Nos. 16 and 17. References to other articles cited are contained in this article.

he states that he repeatedly found in cover-glass specimens from the urethra diplococci which were decolorized by Gram. Once he found the staphylococcus aureus. The normal urethral flora he considers to be non-pathogenic and incapable of surviving long in the urine, although pathogenic bacteria may accidentally be present in the healthy urethra.

The occurrence of the so-called pseudo-gonococci, as first described by Bumm and Lustgarten and Mannaberg in healthy and diseased urethræ, is of importance in reference to the diagnosis of gonorrhœa by microscopical examination. If all of the well-known points, as to the morphology, staining reactions, and enclosure and arrangement within cells, characterizing the gonococcus be observed, most authorities believe that a mistake in diagnosis is possible only in a very small number of cases, if at all. Undoubtedly a microscopical diagnosis of the gonococcus has been made in some cases upon insufficient evidence, and it must be admitted that a positive microscopical diagnosis is sometimes attended with great difficulties. We now possess methods which enable us without serious practical difficulties to isolate and study the gonococcus in cultures.

It cannot be said that investigations have determined satisfactorily the question as to the relative frequency with which the bacteria of cystitis are derived from the urethra or are introduced from without the body. As the bacillus coli communis or the bacillus lactis aërogenes is one of the most common bacteria in cystitis, the infection may often be from the intestinal canal through the blood-current by way of the kidneys; some believe more directly by continuity or by the lymphatic stream from the rectum. These bacilli are, however, widely distributed outside of the body, and may be present around the genitals.

Although the results of the bacteriological examination of the healthy urine are contradictory, the weight of evidence is decidedly in favor of the view that the urine in the *bladder* in health is free from bacteria, and that if urethral saprophytes, or even some pathogenic germs, gain entrance to the bladder, they do not long survive in a healthy person.

The *female urethra* contains bacteria, and the anatomical conditions are more favorable than in the male for the passage of the urethral bacteria into the bladder. Von Gawronsky in sixty-two cases examined found bacteria in fifteen—namely, the streptococcus pyogenes (3), the staphylococcus aureus (8), staphylococcus albus (1), the bacillus coli communis (2), the bacillus tholöeideum (1). This last bacillus is probably a pathogenic variety of the bacillus lactis aërogenes. It is stated that the urethra in these cases was normal.

The *vagina* contains bacteria in varying number and kind. The cervix and uterus are normally free from bacteria. The absence of bacteria from the uterus is not easily explained, but it has its analogy in the absence of bacteria from various other canals and cavities which communicate with passages containing bacteria, as, for example, from the bladder and the bile-ducts. The factors usually cited in explanation of this important provision of nature are mechanical hinderances to the penetration of bacteria resulting from the anatomical structure of the parts and the germicidal properties of the secretions. The principal emphasis is usually laid upon the latter factor.

The bacterial flora of the normal vagina contains various bacilli and

cocci, which do not grow on our ordinary culture media, but can be recognized by microscopical examination. Doederlein[1] has described a non-pathogenic bacillus or a group of bacilli which he has cultivated upon a specially prepared acid medium, and which are characterized by marked acid fermentation of sugar. These vaginal bacilli are regarded by Doederlein as the only bacteria to be found regularly in the normal vaginal secretion, and upon their presence or absence he has based his distinction between normal and pathological vaginal secretions. It has, however, been shown by Krönig and Menge that Doederlein's bacillus is often absent from the normal vagina, and that it cannot, therefore, serve as a distinguishing character of the normal secretion.

According to Krönig[2] and Menge[3] the regular bacterial inhabitants of the normal vagina are obligatory anaërobes, and can be cultivated only in anaërobic cultures. They do not describe in detail the characters of these vaginal anaërobic bacilli and cocci, but they say that they are non-pathogenic. In microscopical preparations Menge found in the normal vaginal secretion of non-pregnant women bacilli more abundantly than cocci, but the latter were never missed. He found Doederlein's bacilli in the minority of cases, and more frequently short, thick rods and delicate, thin, curved rods.

According to Menge, bacteria capable of cultivation in alkaline aërobic culture media are present abundantly near the outlet of the vagina, but are usually absent, and when present only few, in the upper part of the normal vagina. He found only once out of fifty cases examined a pyogenic coccus. This was the streptococcus pyogenes, which existed as a persistent organism throughout the vaginal canal of a non-pregnant woman with gonorrhœa of the cervix and thin cervical discharge. The reaction of the vaginal secretion was alkaline.

Diplococci similar to those from the urethra already described occur also in the vagina, and what was said in that connection as to pseudo-gonococci applies here. Koplik[4] has isolated from the normal vagina of children a white diplococcus, and from the vaginal discharge in simple, not gonorrhœal, vulvo-vaginitis in children two white diplococci and a yellow diplococcus. None of these were decolorized by Gram's method or need be mistaken for the gonococcus.

The question as to the occurrence of pathogenic organisms in the normal vagina has been and is still a subject of vehement controversy among obstetricians, who are divided into two camps as to the desirability of antiseptic irrigations of the vagina and as to the frequency of so-called auto-infection as a cause of puerperal infections. The question is also of interest to the surgeon in relation to hysterectomy and in general to operations involving the vagina and uterus.

The results of different investigators on this point have been extremely divergent, and, notwithstanding the large amount of work done, it is not possible at present to express a final judgment. Some investigators have found pyogenic bacteria frequently in the vagina of pregnant women. Thus, Steffeck found pus-producing organisms in 41 per

[1] Doederlein, *Das Scheidensekret, u. s. w.*, Leipzig, 1892.
[2] Krönig, *Deutsche med. Wochenschrift*, Oct. 25, 1894.
[3] Menge, *ibid.*, Nov. 15, 22, 29, 1894.
[4] Koplik, *Journal of Cutaneous and Genito-Urinary Diseases*, June and July, 1893.

cent. of the twenty-nine pregnant women examined. Others have failed to find pyogenic bacteria, with the exception of the gonococcus, in all of the cases examined, or have met them only exceptionally. Most of the later investigations in which a proper technique was adopted are in accord as to the infrequency with which pathogenic bacteria, with the exception of the gonococcus, are to be found in the vagina of either pregnant or non-pregnant women.

In a bacteriological examination of one hundred and ninety-five pregnant women Doederlein found in 55.3 per cent. acid normal vaginal secretion, according to his definition. The only bacteria were the acid-producing vaginal bacilli. In 44.6 per cent. of the cases he found what he calls pathological secretion, which was feebly acid, neutral, or alkaline, and contained various bacilli and cocci. The streptococcus pyogenes he found in 9.2 per cent. of the so-called pathological secretions, or in 4.1 per cent. of the one hundred and ninety-five cases examined. To the staphylococci present he attributes no importance in the causation of puerperal fever. The oïdium albicans is often found in the vagina, but is without significance as a cause of primary infection.

Krönig found the vaginal secretion of all the pregnant women (about five hundred) whom he examined to be acid, the intensity of the reaction varying in different cases. The bacterial flora was of the same general character as that already described for the normal vagina. In no case did he find the streptococcus pyogenes or pyogenic staphylococci. His conclusion, that the streptococcus pyogenes and the pyogenic staphylococci are never present in the vagina of pregnant women, and that if they should enter they must of necessity be quickly destroyed, cannot be accepted without discrediting the results of other competent investigators, but we may admit that they are present only exceptionally.

Experiments have been made by Krönig and Menge proving that bacteria, including the streptococcus pyogenes and pyogenic staphylococci, introduced, even in large number, into the vagina of pregnant or non-pregnant women, disappear in a short time. Thus, Krönig found that the bacillus pyocyaneus disappeared from the vagina of pregnant women in from ten to thirty hours, the staphylococci in from six to thirty-six hours, and the streptococcus pyogenes, with which only three experiments were made, within six hours. No difference was observed, as to the rapidity with which these foreign organisms disappeared, between the normal and pathological secretions in Doederlein's sense, including those containing gonococci. Menge found in non-pregnant women that the bacillus pyocyaneus disappeared from the vagina on the average in twenty-one hours, the staphylococcus pyogenes aureus in twenty-six hours, and the streptococcus pyogenes in twenty-two hours. In only one case did the vagina become infected, and this was with the staphylococcus aureus in consequence of an accidental injury to the wall. In the other cases the bacteria immediately after their introduction began to disappear. In most instances an increase in the leucocytes in the vagina was observed.

Menge has attempted to discover the factors concerned in the production of this powerful bactericidal property of the vaginal secretion. He attaches some importance to the acid reaction to which Doederlein had called attention as the essential factor, but this cannot be the sole or

the principal factor, as the vaginal secretion of non-pregnant women, although usually acid, may be alkaline, and the bacteria disappeared about as rapidly from the alkaline as from the acid secretion. We cannot at present give any satisfactory explanation of the bactericidal properties of the vaginal secretion.

Irrigation of the vagina with water or with antiseptics diminished the rapidity with which bacteria introduced into the vagina disappeared.

Bacteria introduced into the cervix uteri likewise disappeared in a short time. The secretion here is alkaline.

As a result of the investigations of numerous observers we may conclude that the normal vagina of pregnant and non-pregnant women may contain pathogenic bacteria. With the exception of the gonococcus, such bacteria are not often present, and the vaginal secretion does not, as a rule, permit the prolonged survival of most of the bacteria, including pathogenic forms, which may enter. Powerful as these normal defences are, they may, however, be overthrown under conditions which we now only imperfectly understand.

Much emphasis has been laid upon the fact that pyogenic cocci occasionally found in the vagina have manifested, with few exceptions, little or no virulence when inoculated into animals. It should, however, be remarked that the same negative result of the animal experiment sometimes follows the inoculation of streptococci cultivated from cases of puerperal infection. The animal experiment is not decisive as to the possibilities of these pyogenic bacteria in man, and it has been proven that pyogenic cocci without virulence for animals may infect human beings.[1]

Bacteria in Woman's Milk.—Serious errors of interpretation of their observations have been made by several investigators of the subject of excretion of bacteria by the milk, by not recognizing the fact that milk obtained from the breasts of healthy women regularly contains bacteria. The milk as secreted by the gland is undoubtedly sterile in health, but bacteria derived from the skin are mingled with the milk. These bacteria gain access to the milk in the lacteal ducts within the nipple. By far the most common of these bacteria is the staphylococcus epidermidis albus, described by investigators of this subject as the staphylococcus pyogenes albus. This coccus is a regular inhabitant of the milk in the lacteal ducts near their outlets. Surprise has been expressed by Honigmann[2] and others that of all the cutaneous bacteria this should be usually the predominant or the only one found in the milk, but it appears to the writer that his investigations as to the behavior of this organism in the skin explains satisfactorily the appearance of this coccus in the milk. Of all the cutaneous bacteria, this is the only one which penetrates regularly into the deeper layers of the epidermis and into the glandular appendages of the skin. Occasionally other bacteria, also derived from the skin, are present in the milk. The staphylococcus pyogenes aureus

[1] A full review of the bacteriological literature of the subject of puerperal auto-infection up to the date of its publication, together with the report of original observations, will be found in a paper by J. Whitridge Williams in *The American Journal of the Medical Sciences*, July, 1893.

[2] Honigmann, *Zeitschrift für Hygiene*, Bd. xiv. p. 207.

has been found in the milk of healthy women in a number of instances.

It is not known how far up the lacteal ducts this normal bacterial flora extends. It is probable that the mammary gland conforms in this matter to the behavior of other glands whose ducts open upon surfaces containing bacteria, and that bacteria in demonstrable number are found only in the excretory ducts near their outlets.

As the staphylococci normally present in the milk have the property of coagulating milk, it can hardly be that any considerable multiplication of these bacteria occurs in the milk within the lacteal ducts. Fokker observed a limited germicidal effect of fresh milk in some cases, but Honigmann in a larger number of experiments with proper technique was unable to determine any such property, even as regards the typhoid and the cholera bacilli, which are readily killed by blood-serum.

Sources of the Bacteria in Surgical Infections.

Internal Sources.—We have learned that pathogenic bacteria, and particularly the pyogenic micrococci, may be present upon the skin and various exposed mucous membranes of healthy human beings. These bacteria are of course derived primarily from external sources, but some of them may live for a long time or indefinitely on exposed surfaces of the body, and are found here so often that it is proper to recognize the patient's own body as one source of the bacteria concerned in surgical infections.

Internal sources of wound-infection are in general less commonly operative and less dangerous than the external sources. One explanation of this is that the pyogenic bacteria commonly found in the healthy body are often less virulent than those derived from many external sources. The streptococcus pyogenes when cultivated from healthy mucous membranes is often of very slight or no virulence, as tested upon animals, although occasionally highly virulent streptococci are found under these circumstances. The pyogenic staphylococci, and particularly the staphylococcus albus, are often of greatly attenuated virulence when isolated from the exposed surfaces of healthy persons. The lanceolate micrococcus is present in a virulent state in the mouths of only about 15 per cent. of healthy persons, although it is oftener present in a non-virulent condition. The bacillus coli communis obtained from healthy fæces is usually of very slight pathogenic power.

There are various influences which may be cited to explain the relatively slight virulence of many of the pathogenic bacteria present in the healthy body. Among the most apparent are the struggle for existence with the regular saprophytic flora of the body, the influence of the products of the latter organisms, and especially the antibacterial properties of the fluids, secretions, and living cells of the body. That under circumstances which we at present little understand the bacteria of the body may acquire unwonted virulence seems certain.

Highly virulent staphylococci and streptococci may be present on the exposed surfaces of the healthy body without doing any harm. The protection of the body from infection with the pathogenic bacteria which it often harbors is due not so much to the lowered virulence of these bac-

teria as to the defences which have been set up against their invasion and to the local and general resistance offered to their growth.

These defences may, however, be overthrown, and under these circumstances pathogenic bacteria originally present on exposed surfaces of the body may cause various local and general diseases. The unsatisfactory term "auto-infection" is sometimes applied to diseases thus produced.

The internal organs and fluids of the healthy body are normally free from bacteria. Bizzozero and Ribbert have found bacteria, often within cells, regularly in the lymph-follicles of the normal rabbit's cæcum, and Bizzozero has found spirilla often in the epithelial cells lining the necks of the gastric tubules in dogs. These are the only examples known of the presence of bacteria in the living cells of the perfectly healthy body, and here the bacteria have penetrated only a short distance beneath the free surface.

It is probable that pathogenic as well as other bacteria occasionally get into the tissues and circulation of healthy persons without doing any harm. It is claimed by some that the invasion of bacteria into the healthy body is not uncommon, and this doctrine is called latent microbism by some French writers. The occasional occurrence of suppuration in a simple fracture of bone or in other injured parts remote from an exposed surface is best explained, at least in many cases, by the lodgement of pyogenic bacteria which have been carried from an exposed surface to the part by the blood or lymphatic current, and which presumably would have done no harm without the presence of a locus minoris resistentiæ. The infrequency of this event, however, indicates that the presence of pathogenic bacteria in the internal organs and fluids of the healthy body is exceptional.

Can a wound become infected by bacteria conveyed to it by the circulating blood? This may happen in individuals already infected, although, even when it is certain that pyogenic cocci are present in the circulating blood, a wound may heal without suppuration. The possibility of the infection of a wound in a previously uninfected person by bacteria conveyed by the blood-current cannot be denied, but we possess no stringent proof of such an occurrence, and all experience goes to show that wound-infection from this source must be very exceptional, if it occurs at all.

With proper technique the surgeon has, as a rule, little to fear from the bacteria of the patient's skin as a source of infection of operative wounds. The only bacterium of the skin which is not usually destroyed by thorough disinfection of the surface is the staphylococcus epidermidis albus, which lies often deeper than can be reached by any of the practicable methods of cutaneous disinfection. This coccus is found with great frequency in wounds treated aseptically or antiseptically, but ordinarily it does not interfere with the process of repair. Under certain circumstances, particularly when foreign bodies are introduced into the wound or when there is strangulated tissue in the wound, it may cause rise of temperature and suppuration. It is the most common cause of stitch-abscesses. It is often associated with other bacteria in suppuration of external wounds and in inflammations involving the skin. It is identical with, or simply a variety of, the staphylococcus pyogenes albus,

but for reasons which have been stated the latter name seems inappropriate for this ordinary, harmless skin coccus. This white staphylococcus is a widely-distributed organism, and it may enter a wound from without as well as directly from the surface of the body.

The source of the bacillus pyocyaneus in wounds is often from the skin of the patient, but this is a widely-distributed organism, and it may also enter from without.

The mucous membranes which normally harbor bacteria on their surface cannot be completely disinfected by any practicable methods, although it is possible to reduce the number of bacteria, in some situations more readily than in others. The utility of attempting before operation disinfection of a mucous surface—as, for example, in operations involving the conjunctiva, mouth, rectum, and the lower genito-urinary tract—must be determined by experience, and on this point the views of surgeons are not in harmony.

Bacteria cannot be completely kept out of wounds of exposed mucous membranes. The kinds of bacteria in the patient's body which are likely to enter such wounds and the special conditions relating to the bacterial flora of the different mucous membranes have already been described. Although wounds involving such mucous membranes as those of the mouth and intestine, which contain vast numbers of bacteria, including often pyogenic varieties, often heal satisfactorily, and even by first intention, the surgeon has no such guarantee of securing primary union as in operative wounds through the skin. The fact that these wounds often heal quickly and without suppuration demonstrates that the mere presence of certain bacteria, even in large number, in a wound does not necessarily interfere with healing. It also supports the view already advocated that the pyogenic cocci often present on certain exposed mucous surfaces are usually of weakened virulence. But the main factor is, after all, the vital resistance of the living tissues to bacteria, including many virulent species.

The pathogenic bacteria often present on the exposed surfaces of the healthy body are, however, of surgical interest, not so much as a source of primary wound-infection, but rather as the specific agents of infection in various local and general surgical diseases. As examples of local diseases of this category may be cited otitis media, appendicitis, perforative and other forms of peritonitis, some cases of cystitis, and certain abscesses. The pneumonias, localized abscesses, pyæmia, and septicæmia which are such frequent complications of diphtheria and certain general diseases, as typhoid fever and other infectious fevers, are due in many instances to the secondary invasion of pathogenic bacteria, particularly pyogenic cocci, normally present on mucous membranes. It is chiefly from the mouth, tonsils, pharynx, and intestine that these invaders enter the body. The primary disease is often one which is attended by some lesion of the mucous membrane which opens the way for the passage of the micro-organism. But it is not enough for the gate to be thrown open. The defenders within must be overcome. Hence it is particularly in conditions where the vital powers of resistance are lowered that we meet with affections caused by the invasion of pyogenic bacteria from the exposed surfaces of the body. That under these conditions, as

well as under others, attenuated bacteria of the body may become exalted in virulence is highly probable.

The term "auto-infection" is associated particularly with the discussions on the causation of puerperal fever. The bacteriological data entering into this discussion have been given in describing the bacteria of the vagina. The evidence is contradictory, but on the whole is opposed to recognizing so-called auto-infection as a cause of puerperal fever, save in a small proportion of cases.

The bacteria most often found in cystitis are such as might readily gain entrance at times to the healthy urethra, but in most cases of this disease, as in so many others, an essential etiological factor is some primary damage to the part, which permits the survival and growth of the invading micro-organisms.

The most common secondary invader of the body is the bacillus coli communis. The first observations of the general invasion of the internal organs of the body by the colon bacillus were made by the writer and reported in May, 1890. We have found in 40 per cent. of the autopsies at the Johns Hopkins Hospital the colon bacillus in one or more of the internal organs, those most frequently invaded being the lungs, kidneys, liver, mesenteric glands, and gall-bladder. In the great majority of these cases the colon bacilli were present without any organic lesion which could be referred to them. Intestinal lesions were found in 75 per cent. of our post-mortem cases of invasion of the colon bacillus. Very little importance is to be attached to the demonstration of this bacillus in internal organs of the body at autopsies in cases without any lesion which can be referred to it.

The fact that the colon bacillus is found with great frequency in internal organs of the body after death from all sorts of causes, and without doing any manifest injury, necessitates caution in the interpretation of cases where its presence is associated with definite lesions. That in some of the cases reported as infections by this bacillus its presence was only that of an accidental, secondary invader seems to the writer certain. There can be no doubt, however, that under certain conditions the colon bacillus may be pathogenic. It is prone to settle in parts already damaged either by some other micro-organism or by some non-infectious agent. In forty-eight cases of acute inflammation, of various kinds and situations, in which we found the colon bacillus, it was the sole organism present in only fourteen. In the majority of cases of appendicitis and of perforative peritonitis we have found associated with the colon bacillus other bacteria, and particularly the ordinary pyogenic cocci. There is reason to believe that the highly resistant colon bacillus may survive in an inflamed part after the primary organism which started the trouble has died out or has been crowded out by the invader.

The colon bacillus has been repeatedly observed alone or in combination with other bacteria in wounds. That it may be the primary infectious agent in various surgical and other inflammations in different parts of the body is established by numerous observations.

The bacillus lactis aërogenes, which most investigators no longer attempt to separate sharply from the bacillus coli communis, is likewise a common invader from the intestinal tract under conditions similar to those relating to the colon bacillus and with similar pathogenic effects.

The streptococcus pyogenes is a far more important cause of surgical infections than is the colon bacillus. It is more commonly present than other pyogenic cocci in appendicitis, peritonitis, and other inflammations of serous membranes, and in septic infections secondary to other diseases. It is a frequent cause of secondary inflammations in the lungs, serous membranes, and other parts, and of general septicæmia in diphtheria, tuberculosis, scarlet fever, typhoid fever, and other infectious fevers, and also in many non-infectious diseases. The source of these various secondary streptococcus infections is often from the mouth, tonsils, throat, and intestine, parts which in their normal condition often harbor streptococci.

Of other bacteria more or less frequently present on exposed surfaces in health, and concerned in various surgical infections, may be especially mentioned the staphylococcus aureus and albus, the micrococcus lanceolatus, the bacillus pyocyaneus, the micrococcus tetragenus, bacillus proteus, and the bacillus of Friedländer.

EXTERNAL SOURCES.—Bacteria derived from without the body are those chiefly concerned in infections of wounds and most other primary surgical infections. Abundant experience has demonstrated that if all pathogenic bacteria from external sources, as well as those which may happen to be upon the surface of the skin, be kept out of an external wound, no suppuration of the wound occurs.

There are two ways by which external bacteria may enter a wound: one is by contact with objects contaminated with bacteria; the other is by the air. Strictly speaking, air infection is also contact infection, but the distinction implied in the customary use of these terms is a useful one. Experimental and clinical observations have shown conclusively that contact infection is far more dangerous and common than air infection.

The main emphasis of modern surgical technique is laid upon the sterilization of all objects, such as instruments, ligatures, dressings, and the hands of operator and assistants, which are brought into contact with the wound. The principal sources of contact infection of wounds, as enumerated by Park,[1] are the skin and hair, instruments, sponges or their substitutes, suture material, the hands of the surgeon and his assistants, drainage materials, dressing materials, miscellaneous—*e. g.* drops of perspiration, an unclean irrigator-nozzle, the nail-brush, the clothing of the operator or the bystanders, etc. Of these objects the most difficult to disinfect is the skin. We have already considered this subject, so far as it belongs to this article, in describing the bacteria of the skin.

The pyogenic cocci, which are the bacteria concerned in the great majority of cases of wound-infection, are ubiquitous, and it would be useless to attempt to specify all the objects upon which they have been found. The source from which these cocci are derived is not, however, a matter of indifference. The pyogenic cocci, and particularly the streptococcus, derived from infected persons, as from a case of erysipelas or peritonitis or septicæmia, are more likely to cause serious infection of wounds than cocci of the same species derived from other sources.

Of other bacteria sometimes concerned in wound-infection, the bacillus coli communis not only is a constant inhabitant of the normal intestine,

[1] Roswell Park, "Wound-infection," *American Journal of the Medical Sciences*, Nov., 1891.

but is widely distributed in external nature, and the bacillus pyocyaneus, often present on the healthy skin, is likewise a widely-distributed organism. The bacillus pyocyaneus is a comparatively harmless organism in external wounds, but it is capable of exerting serious pathogenic activity, especially in infections from the intestine. The soil is the natural home of the tetanus bacillus, which is abundant in certain localities and rare in other places. It has been found with especial frequency in garden earth and about stables. It is present very commonly in the fæces of herbivorous animals, as has already been mentioned. Sormani observed that tetanogenic material introduced into the alimentary canal of dogs, which subsequently were prevented from receiving additional tetanus bacilli, could be demonstrated as long as sixteen days after its reception. The bacillus of malignant œdema is likewise a common inhabitant of the soil. In infected localities the anthrax bacillus lives in the soil. In fact, the upper layers of the soil are the great home of bacteria of all sorts, and pyogenic cocci have been found in this situation. The proteus bacillus, which is capable of assuming pathogenic activity, is commonly found in decomposing animal substances.

Flies and other insects may be the carriers of all sorts of infectious agents. Pyogenic staphylococci have been found in the excrements of flies, and even the susceptible cholera bacillus passes unharmed through the alimentary canal of flies.

Certain surgical infections are associated particularly with injuries from definite objects, as, for example, necrogenic warts, containing tubercle bacilli, from cadavers; zoonotic erysipeloid from crabs and other shellfish; oyster-shucker's keratitis; actinomycosis from oats and other grains; anthrax from hides, wool-sorting, and other handling of material from infected animals.

It has been demonstrated by La Garde[1] that bullets obtained from previously unopened boxes as sent out by the manufacturer are practically sterile, but that if the bullets become contaminated with pathogenic bacteria, the latter are not destroyed in the discharge and transit of the bullet, and are capable of infecting wounds. He was able to infect rabbits with the streptococcus pyogenes and other pathogenic bacteria by firing infected bullets through the ear.

As compared with contact infection, infection of wounds from the air is of minor importance, but surgeons are not agreed as to whether or not the dangers of air infection are so slight under ordinary conditions that they need not be taken into consideration at all. In the early days of antiseptic surgery bacteria of the air were thought to be frequent agents of wound-infection and the carbolic spray was introduced by Lister with the intention of destroying them. There followed a period when surgeons considered that the air bacteria could be wholly neglected as a source of traumatic infection, and this is probably still the opinion of the majority of surgeons. At present there is a tendency again to pay more attention to the possibilities of infection from this source, and some surgeons have even gone back to the use of the spray.

Bacteria are always present in the air over the ground and around human habitations, whereas sea-air at a considerable distance from land

[1] La Garde, *New York Medical Journal*, Oct. 22, 1892.

and the air at high altitudes is nearly or quite free from micro-organisms. Bacteria do not usually occur in the air as single, detached cells, but rather as clumps attached to particles of dust, so that in a perfectly quiet atmosphere, as in a closed room, these particles containing bacteria rapidly settle upon underlying objects. Bacteria, being thus attached to particles of dust, are readily filtered out from the air by passing it through porous substances, such as cotton-wool. The bacteria are carried down by drops of rain, and the air of a room may be freed from floating bacteria by producing an artificial rain by some form of douche or spray apparatus.

Whatever creates dust, such as the entrance or exit of a body of students, and other movements in a room, brings bacteria into the air.

It is a fact of fundamental hygienic importance that fine particles, including bacteria, are not detached from moist surfaces even by strong currents of air. Hence comes the hygienic value of using moist cloths in removing dust and in cleansing a room. Substances containing infected material should not be allowed to dry under conditions in which dust therefrom can be conveyed into the air. In the present era of dry dressings for wounds there is frequent opportunity for the scattering of dust from the discharges dried on the dressings in the removal and subsequent handling of these dressings, unless especial care be taken to prevent this in all cases where pathogenic bacteria may be present.

The number of bacteria in the air varies greatly under different conditions. In general it may be said that living micro-organisms are less abundant in the air than was formerly supposed. They cannot multiply in the air, and only those whose vitality is not destroyed by drying can exist in the air. Desiccation may lessen the virulence of pathogenic bacteria without actually destroying them.

What interests us chiefly in this connection is to know whether pathogenic bacteria, and more particularly the pyogenic cocci, occur in the air, and, if so, how frequently and under what conditions.

Pyogenic staphylococci and streptococci have been repeatedly found in the air, although generally only in small number. Obtained from this source, these cocci are often of only slight virulence, but highly virulent staphylococci and streptococci have been isolated from the air. Among those who have isolated pyogenic cocci from the air may be especially mentioned von Eiselsberg, Emmerich, Neumann, Prudden, Ullmann, Haegler, C. Fraenkel. Haegler[1] demonstrated that streptococci may preserve their vitality and power of development for at least thirty-six days, and staphylococci for one hundred days, in pus dried on bandages.

Pyogenic staphylococci and streptococci have been found far more frequently in hospital wards and operating amphitheatres than elsewhere. Haegler found staphylococci and streptococci in the majority of his examinations of the air in the wards and operating-rooms of the hospital in Basle, and the number of such cocci present was in general proportionate to the opportunity for entrance into the air of cocci from dry material and to the amount of stirring up of dust by movement in the room. He also detected in a number of instances the bacillus pyo-

[1] Haegler, *Beiträge zur klinischen Chirurgie*, Bd. ix. p. 496.

cyaneus in the air. Streptococci have been found frequently in the air of rooms containing cases of erysipelas.

Haegler found the pyogenic cocci on the hair and coats of surgeons, and in cobwebs in hospital rooms, as well as on other objects. He concludes from his investigations that the danger of infection from the air is greater than is assumed by many surgeons.

Schimmelbusch and some other investigators have found pyogenic cocci very rarely in surgical wards and operating-rooms. It is sufficiently apparent that various circumstances, such as the care exercised in the destruction or sterilization of material infected with discharges, the use of disinfectants, the isolation of infected cases, and the observance of strict cleanliness, must influence the results of these examinations of the air of hospitals, and that the danger of air infection may be considerable in one place and reduced to a minimum in others.

Air infection may readily become contact infection by bacteria from the air being deposited upon the hands of the operator or his assistants, upon instruments, dressings, or other objects which are brought into contact with the wound.

Micro-organisms which are capable of development only within the living body are called obligatory parasites. A facultative parasite is one whose ordinary mode of life is saprophytic, but which is capable of a parasitic existence, and a facultative saprophyte is one whose ordinary existence is parasitic, but which can grow outside of a living host. These distinctions, however, cannot always be sharply carried out in practice. Although we can cultivate the gonococcus outside of the body in specially prepared artificial media, there is no reason to suppose that it multiplies, or even long survives, in the outer world under ordinary conditions, and immediate contact with the infected person is the principal source of infection. The tubercle bacillus also can be cultivated artificially, but conditions must be exceptional which permit its multiplication outside of the body. Unlike the gonococcus, the tubercle bacillus is capable of prolonged survival outside of the body, and, as is well known, it is a widely-distributed organism. The leprosy bacillus has not been cultivated artificially, and it is ranked among the obligatory parasites. Intimate contact with an infected person seems to be the usual source of infection, although opinions are divided as to the mode of transmission of this disease. The micro-organisms causing syphilis and hydrophobia are unknown, but they are doubtless obligatory parasites.

The bacteria causing anthrax, tetanus, malignant œdema, and actinomycosis are facultative parasites. The pyogenic cocci find the best conditions for their multiplication in the living body or material rich in organic matter, but these ubiquitous bacteria can often find natural opportunity for multiplication outside of the body.

The only bacteria infectious for human beings which are positively known to develop spores are the bacilli of tetanus, anthrax, and malignant œdema, all killed by exposure in a moist condition for a few minutes to boiling temperature. It is generally stated that the tubercle bacillus forms spores, but this is not positively demonstrated. There is still greater doubt as to the formation of spores by the bacilli of glanders, typhoid fever, and leprosy. The tubercle bacillus, the pyogenic

cocci, and the typhoid bacillus are among the more resistant bacteria which are not proven to form spores.

Portals of Entry of Bacteria in Surgical Infections.

The portals of entry or atria of infection are the skin and the exposed mucous membranes of the respiratory, alimentary, and genito-urinary tract, and wounds of these surfaces. The fœtus may become infected either by germinal, or far more frequently by placental, transmission of infectious micro-organisms. In our laboratory experiments we rarely imitate the precise conditions of natural infection, but we make frequent use of methods of inoculation which occur only exceptionally or not at all under natural conditions, such as the injection of bacteria directly into the vessels, into the serous cavities, and beneath the skin, and forced inhalations of large numbers of micro-organisms.

Most of the bacteria concerned in surgical infections are capable of entrance through any portal and of producing infection in any part of the body, but there are some which are restricted to certain modes of entrance and to certain parts of the body. Examples of the latter group are the bacteria causing gonorrhœa and tetanus.

Let us consider briefly the defensive arrangements which exist normally at the various portals of entry. These are partly mechanical, and due to the anatomical structure of the part. The thick epidermal covering of the skin and orifices of the body is impenetrable to most bacteria. The thick layer of laminated flat epithelium covering the mucous membranes of the mouth, œsophagus, and vagina is a hardly less efficient mechanical protection. The more delicate mucous membranes covered by cylindrical epithelium are so situated as to be less exposed to injury, but even these surfaces do not ordinarily permit the penetration of bacteria without the occurrence of some damage to their integrity. The ciliated epithelium of the respiratory tract drives foreign particles toward the natural outlets. The tortuous arrangement of the upper air-passages filters out most of the bacteria which are inhaled. Bacteria which may happen to enter the bladder or uterus or the glandular ducts, such as the salivary, biliary, or pancreatic, which are normally free from bacteria, would be likely to be discharged with the secretions. Obstruction of these ducts predisposes to their infection.

There are certain situations, particularly the tonsils and the lymphatic follicles of the intestine, which, by the delicate nature of their covering, are especially exposed to the invasion of bacteria. These are vulnerable parts, as is shown by the frequency with which primary and secondary infections start from them, but there is reason to believe that the lymphatic tissue in these situations is richly endowed with vital properties hostile to the development of bacteria.

Of equal importance with these mechanical defences are the antibacterial properties of the secretions on mucous membranes. These properties depend partly on the chemical reaction (gastric juice, vaginal secretion), partly on the antagonism offered to invaders by the regular bacterial flora of the surface, but mainly upon bactericidal qualities at present little understood as to their cause, but unquestionable as to their existence.

Micro-organisms find at the gates of entrance living cells and fluids which in health are capable of destroying many of them, and if they pass these gates, it is usually only to be arrested and destroyed at the nearest lymphatic glands. Nor are these protective agencies limited to the lymphatics or to any particular organs: they are present in the blood and everywhere throughout the living body, although more highly developed in some places than in others. Whether the battle against the invaders be within the cells, as is assumed in the phagocytic theory, or outside of the cells, the weapons of attack must be furnished by the cells. The living body is amply protected in health against all ordinary bacteria which may seek entrance, and the study of the etiology of infectious diseases involves the consideration not only of the characters of the specific agents of infection, but also of the ways in which the natural defences of the body have been overcome. There are infectious micro-organisms to which the healthiest and strongest body is able to offer no resistance, and there are other micro-organisms which are capable of doing harm only when the vital resistance of the body has been lowered.

Can micro-organisms penetrate the intact skin or mucous membranes, or must there always be some pathological change or lesion of continuity of these parts to permit their entrance? This question has been variously answered, but, at least as far as certain membranes and certain micro-organisms are concerned, the evidence must be regarded as conclusive for the affirmative answer. It cannot be doubted that the infectious agents causing malaria, relapsing fever, and the eruptive fevers may enter the body without any defect in the skin or mucous membranes, but our concern is not with this class of diseases.

Garré,[1] in 1885, was the first to make a self-sacrificing experiment which has since been repeated with similar result by several others. He rubbed into the skin of his forearm, in the same way as one would rub in an ointment, a large quantity of a virulent culture of the staphylococcus pyogenes aureus. The skin was left intact. After six hours a prickling sensation, associated with redness and turgescence, developed, and in a few hours more about twenty pustules, each developing about a lanugo hair, had formed. In the course of four days an extensive carbuncle, which discharged pus through seventeen openings, formed, and the axillary glands were swollen.

The largest number of experiments of this character have been by Wasmuth.[2] The experiment succeeds almost invariably when virulent staphylococci are thoroughly rubbed into the human skin, but fails almost constantly to give a positive result upon the skin of animals (rabbits, guinea-pigs). The failure with animals is not due to greater impenetrability of their skin to bacteria, for anthrax bacilli and some other pathogenic bacteria when rubbed into the skin of animals are capable of causing infection. Animals are less susceptible than man to these pyogenic cocci—a fact which should not be lost sight of in drawing inferences applicable to man from experiments upon animals with these organisms. Büdinger has shown that pyogenic cocci nearly devoid of virulence for animals may produce abscesses when rubbed into the human skin.

[1] Garré, *Fortschritte der Medicin*, Bd. iii. p. 165, 1885.
[2] Wasmuth, *Centralblatt für Bacteriologie*, Bd. xii. pp. 824 and 846, 1892.

The mere application of the bacteria to the surface of the skin produces no infection either in man or animals. The bacteria must be well rubbed in or pressed in to cause infection.

Through what channels do the bacteria penetrate the skin in these experiments? There are three possibilities—namely, through the epidermis into the rete Malpighii, into the sweat-glands, or into the hair-follicles and sebaceous glands. Schimmelbusch, Machnoff, and Wasmuth have demonstrated that they enter by way of the hair-follicles, and the last-named author considers that they can enter the intact skin in no other way. He finds a principal support for this view in the fact that he was unable to produce any effect by rubbing the cultures into the skin of the ball of the thumb, where there are no hair-follicles, and in the actual demonstration by himself and previous experimenters of the bacteria in the hair-follicles. This conclusion is in accord with the clinical fact that furuncles form almost exclusively in parts of the skin provided with hairs and sebaceous glands, and often begin as pustules around the hairs.

The objection may be raised that these experiments do not actually prove the possibility of infectious agents penetrating the intact skin, as microscopical lesions may be caused by the rubbing or the pressure. Macroscopical and microscopical examinations, however, failed to show any lesion of the epidermis. Still, a microscopical defect might be difficult to detect, and Schimmelbusch considers it possible that in these experiments a minute breach of continuity may be produced.

As experiments upon rabbits with bacilli of anthrax and of rabbit septicæmia have shown, general as well as local infection may follow the rubbing of certain pathogenic bacteria into the skin. These experiments simply show that certain pathogenic organisms are capable of settling in the healthy skin and causing local infections, which may, however, be the starting-point of general infections. They do not show that microorganisms can pass through the healthy skin and thence invade the body without producing any damage at the point of entrance. It is a well-known clinical fact that in wounds this local damage may be very slight and readily overlooked. Indeed, there is a certain antagonism between the extent of the local infection at the point of invasion and the likelihood of general infection.

We have no conclusive experimental evidence that bacteria can enter the circulation through an intact mucous membrane without causing any lesion whatever at their point of entry. There are, however, many examples of pathogenic bacteria which are capable of attacking a healthy mucous membrane and of producing local and general infection through this channel. The lesion of the mucous membrane in some of these cases may be slight and not readily demonstrable. The gonococcus is certainly capable of infecting an intact mucous membrane. A large number of infectious diseases can be produced by feeding cultures or material containing certain pathogenic bacteria. Examples of such intestinal infections are tuberculosis, anthrax, typhoid fever, Asiatic cholera, hog cholera, and chicken cholera. As has already been mentioned, the points in the alimentary canal most vulnerable to infection are the tonsils and the lymphatic follicles.

As is well known, indifferent foreign particles, such as coal-dust, may

be taken up from the air-cells of the lungs and conveyed by the lymphatic current to the bronchial lymphatic glands, but under normal conditions these particles do not enter the general circulation. It is probable that bacteria may be disposed of in the same way. It is said that some of the bacteria of the septicæmias of animals—as, for example, the bacillus of rabbit septicæmia—may enter the circulation through the lungs without leaving behind any manifest lesion. We have no conclusive evidence that the micrococcus lanceolatus, the streptococcus pyogenes, or the other pyogenic bacteria can pass through the intact lungs into the general circulation without causing some inflammation of the lungs.

The lungs possess the power of disposing of many pathogenic bacteria which have been introduced into them. There have been many experiments made to determine the possibility of infection with anthrax bacilli by way of the lungs, and the conclusions drawn from them have been widely divergent. Buchner and his pupils claim to have succeeded, but Baumgarten and his co-workers reached a different conclusion. Gramatschikoff finds that the intratracheal injection of anthrax bacilli or spores is incapable of causing infection if infection through the wound be avoided. The bacilli quickly perished in the lungs, sections showing degenerated bacilli within four to ten hours.

No infection of an intact mucous membrane, either in man or animals, has been produced experimentally by the mere application to the surface of the membrane of the pyogenic cocci, although there is clinical evidence of the possibility of such a mode of infection.

The chief surgical interest of the question of the permeability of intact mucous membranes to bacteria relates to the explanation of tuberculosis of internal parts without tubercular lesion at any portal of entry, and to cases of osteomyelitis, internal abscesses, and, in general, the cases of so-called cryptogenetic septicæmia and pyæmia, in which the most careful examination fails to detect any point where the bacteria could have entered.

Most authorities are of the opinion that tubercle bacilli can pass through a mucous surface without leaving any trace behind of their presence at the point of entrance. The main support for this doctrine of the passage of tubercle bacilli through intact mucous membranes is found in the clinical facts. Orth and Wesener, however, claim that occasionally animals fed with tubercle bacilli develop tuberculosis of the mesenteric glands without any tubercular alteration of the intestinal mucous membrane. Baumgarten contests this, and holds that in all cases of experimental tuberculosis there is a tuberculous lesion at the point of entry. He explains the cases of tuberculosis of lymphatic glands, of bone, and of other parts observed not infrequently in man without tuberculosis of the lungs or any exposed surface by assuming that they are all instances of inheritance of tubercle bacilli. This well-known doctrine of Baumgarten involves also the assumption that tubercle bacilli may remain for an indefinite time alive within the body in a latent condition.

In the opinion of the writer the evidence is in favor of the view that tubercle bacilli may enter the lymphatic circulation without causing any tuberculous affection at the point of entrance. In many cases, however, where this explanation might at first be thought to be the correct one,

careful search will reveal the atrium morbi, not infrequently in the form of a small healed tuberculous focus in the lungs or other exposed part. H. P. Loomis has found tubercle bacilli in the bronchial glands without tuberculous lesion in any part of the body.

It is not possible at present either to prove or to disprove, for man, the possibility of the passage through an intact mucous membrane of the pyogenic cocci, which are the organisms usually concerned in the so-called cryptogenetic pyæmic and septic processes. It is true that the most careful examination in many of these cases fails to reveal the atrium of infection, but who can say that it may not have been overlooked? The more painstaking the search, the more likely is some portal of entry to be found. This portal may be the root of a carious tooth, the middle ear, one of the nasal sinuses, or some other part not usually examined at autopsies. Who can feel sure that in the whole vast extent of the alimentary, respiratory, or genito-urinary mucous membranes some minute lesion, serving as a point of entry, does not exist? Such a lesion may be microscopic in size, perhaps no more than a necrotic epithelial cell. Moreover, we have to consider that the original lesion at the point of entry may have healed without leaving any recognizable trace; nor need this lesion be a recent one. There are instances of fatal septicæmia following mere punctures and scratches of the skin which gave rise to scarcely any local inflammation, and the septicæmia may develop after the point of original injury has healed and been forgotten. Bacteria, including pathogenic species, may remain alive, but quiescent, for weeks and months, in some instances it would seem even for years, within the body, and then, as the result of a trauma or some other cause, their pathogenic energies may be stimulated into activity.

While it is certain that in many instances pathogenic micro-organisms may invade an intact mucous membrane and cause local and general infection, and that in some instances the organism may enter the circulation and be transported to distant parts without manifest lesion at the point of entrance, and while the possibility of the latter occurrence cannot be disproven in the case of the pyogenic cocci, nevertheless there can be no doubt that pathological alterations and wounds of the exposed surfaces of the body open the way for the entrance of the pathogenic micro-organisms in most surgical infections. For some pathogenic organisms, including pyogenic cocci of exalted virulence—such as may come from a case of puerperal peritonitis, for example—all that is needed is that the parts should be thus opened, and infection is sure to follow their entrance. But we have only to contrast the frequency with which streptococcus and other pyogenic infections complicate or follow the infectious fevers, such as typhoid, characterized by lesions of mucous membranes, or the frequency with which infection follows external wounds in diabetic and dropsical persons, with the rarity of such a sequel to injuries of the same parts in a healthy person, to appreciate the importance of other factors than the mere breach of continuity in an exposed surface in predisposing to local and general infections. We shall consider later these local and predisposing causes of surgical infections.

Interesting experiments have been made by Schimmelbusch, Nissen, Pfuhl, and others as to the rapidity of absorption of bacteria from fresh

wounds. They have demonstrated that bacteria are taken up within a very short time, by the lymphatic and blood-vessels, from a fresh bleeding wound. Mice inoculated with anthrax bacilli at the tip of the tail died of anthrax in spite of amputation of the tail ten minutes after the inoculation. Nissen found anthrax bacilli in the nearest lymphatic glands within one hour and a half after peripheral inoculation of an extremity. The application to smooth fresh wounds by Schimmelbusch of a moderate quantity of a culture of the anthrax bacillus or of a streptococcus lethal to mice was fatal, notwithstanding an immediate attempt at disinfection of the wound with the strongest antiseptics. Schimmelbusch and Ricker[1] were able to demonstrate in cultures from the internal organs (lung, liver, spleen, kidney) anthrax bacilli in an hour, or even half an hour, after the inoculation of fresh wounds of mice with this organism. They showed that this rapid absorption of bacteria from fresh bleeding wounds applies equally to pathogenic and saprophytic bacteria. In cultures from the internal organs made five minutes after the infection of a fresh wound of a rabbit's thigh with the bacillus pyocyaneus they found many colonies of this bacillus. In making the cultures it is necessary to use the whole organ finely divided.

The significance for the individual of the rapid absorption of bacteria from fresh wounds depends, of course, primarily, upon the character of the bacteria. If these in small or moderate number are capable of causing fatal septicæmia, as is the case with virulent anthrax bacilli in highly susceptible animals, the issue is necessarily fatal; if, as is the case with the pyogenic cocci, the bacteria do not readily gain a foothold where they can multiply, their absorption is of little consequence in most cases, and, so far as the ordinary saprophytes are concerned, their absorption from fresh wounds is a matter of indifference.

The period during which this rapid absorption of bacteria from a fresh wound takes place is of short duration. As soon as a coagulum has formed on the surface of the wound and the open mouths of the lymphatic and blood-vessels are plugged, the conditions are changed, and fine particles like bacteria are no longer quickly transported into the lymphatic and blood circulation. The surface of a healthy granulating wound offers great resistance to the invasion of bacteria, almost as much as an intact exposed surface of the body. Slight injuries, however, such as probing, the removal of dressings, and other manipulations, may convert a granulating surface into a fresh wound, with the accompanying dangers of infection.

Elimination of Bacteria in the Secretions.

In former times it was thought that the body gets rid of infectious agents chiefly by their excretion through the emunctory channels. We now know that micro-organisms are destroyed within the body by the living cells and fluids, and that this method of freeing the body from living bacteria is far more efficient and of much greater importance than that of their excretion by the emunctories.

Pathogenic bacteria often appear in the secretions in various infectious

[1] Schimmelbusch, *Deutsche med. Wochenschrift*, July 12, 1894.

diseases, and it is of interest to know under what conditions they are excreted and in what secretions they occur. The mode of conveyance of infectious organisms from an infected individual to others, and the practical measures of prevention, are determined in large measure by the manner of elimination of these organisms from the infected body.

Wyssokowitsch, as the result of a long series of experiments, came to the conclusion that bacteria in the circulation are never discharged from the body through the healthy organs, but escape only through some breach of continuity or other lesion in the excretory membrane. Hence those pathogenic bacteria which cause some damage to the excretory surfaces—and there are many such bacteria—are most likely to appear in the excreta, although bacteria without this capacity may escape through lesions preformed from other causes.

Not all subsequent investigators of this subject have been able to confirm this law of Wyssokowitsch, and it is true that bacteria may be eliminated from the circulation by way of the excretions without demonstrable lesion of the organ through which they have passed. It is to be remembered, however, that the lesion may be difficult to detect, or may be of some such undemonstrable character as that of the vascular walls in inflammation which permits the passage of leucocytes and red blood-corpuscles.

There have been many special and incidental investigations of the subject of the escape of bacteria with the secretions. Of the experimental investigations relating to the subject in general the most important are those of Wyssokowitsch, Pernice and Scagliosi, and Sherrington.[1]

Sherrington experimented on mice, rabbits, and guinea-pigs by the subcutaneous or intravenous inoculation of eleven, mostly pathogenic, species of bacteria. In sixty-eight observations the presence of the specific micro-organism introduced was detected in the urine twenty-one times; on eight of these twenty-one occasions the presence of blood in the urine was ascertained by the spectroscope; and in a ninth case gross lesions (tubercle) were found in the kidney. Sometimes the urine contained much coagulable albumin. Of the bacteria of surgical importance tested, the staphylococcus aureus, the bacillus pyocyaneus, the bacillus anthracis, and a bacillus probably identical with the Friedländer bacillus were found frequently in the urine. In forty-nine experiments the specific bacilli were found in the bile in eighteen. The bacillus of mouse septicæmia appeared in the conjunctiva, which became inflamed, under conditions making it probable that it did not enter from without. Among the points especially emphasized by Sherrington are the following:

"At a time when every drop of the circulating blood is teeming with micro-organisms there may not be the slightest transit of them into the urinary and biliary fluids then secreted, and they may be completely absent from the aqueous humor of the eye-ball."

"When certain pathogenic species are employed, a number, often very considerable, of the injected bacteria tend after a time to appear in the secretions of the kidney and liver, and their escape in the secreta is

[1] Sherrington, "Experiments on the Escape of Bacteria with the Secretions," *The Journal of Pathology and Bacteriology*, Feb., 1893. This valuable article contains a full review of the literature.

sometimes accompanied by an escape of actual blood," although not infrequently there is no blood in the secreta.

"The evidence is against believing that when this transit of bacteria across the secreting membrane occurs the membrane is still normal in condition, although at the same time it need not be ruptured or pervious to red blood-corpuscles."

"The fact that the escape of the bacteria tends to occur, not immediately upon the introduction of them wholesale into the circulation, but in the late stages of the communicated disease, suggests that the healthy secreting membranes are not pervious to bacteria, and that only after soluble poisons produced by the infection have had time to act upon them do the membranes became pervious to the germs. The fact that species which are innocuous did not in the experiments appear in the secreta at any time is in conformity with this conclusion."

Pernice and Scagliosi experimented with staphylococcus aureus, bacillus prodigiosus, bacillus anthracis, bacillus pyocyaneus, and bacillus subtilis, and they found that these bacteria were constantly excreted through the urine and bile, and might escape through various mucous membranes. This excretion begins six to eight hours after their introduction. Virulent bacteria retain their virulence, as a rule, in the excreta.

There are numerous observations in human beings of the escape of infectious bacteria through the excretions. The pyogenic cocci are particularly prone to settle in the kidney and cause focal inflammations, but even without actual foci of suppuration they often escape into the urine. Nannotti and Baciochi, both in grave suppurative processes and in slight ones, found the specific bacteria with great frequency and of customary virulence in the urine. They disappeared from the urine twenty-four to thirty-six hours after the evacuation of the pus. In experimental pyocyaneus infections the specific bacillus is found regularly in the urine. The micrococcus lanceolatus in pneumonia and other pneumococcus infections, the typhoid bacillus in typhoid fever, the streptococci in erysipelas and other streptococcus infections, are often present in the urine. The bacillus coli communis, the most common of all secondary invaders, often escapes through the kidney.

Pathogenic bacteria are eliminated very often through the bile. One of the most common lesions in various infectious diseases is the presence of focal necroses, sometimes visible to the naked eye and sometimes seen only with the microscope, in the liver, and these permit the passage of bacteria into the bile. It is not, however, necessary that such necroses should be present in order to permit the escape of bacteria into the bile.

Blachstein, in experiments made under the direction of the writer, demonstrated that the colon bacillus and the typhoid bacillus injected into the veins of rabbits often appeared in the bile, where they frequently remained alive and in large number weeks and months after they had disappeared from all of the internal organs. In many of these cases there were focal necroses in the liver. The passage from the circulation into the bile of the anthrax bacillus, of the micrococcus lanceolatus, the streptococcus pyogenes, the pyogenic staphylococci, the bacillus pyocyaneus, and of other bacteria has been repeatedly demonstrated. Patho-

genic bacteria are quite as frequently discharged through the bile as through the urine.

Of course bacteria in the bile will enter the intestine with this secretion, and it is therefore not always easy to determine whether specific pathogenic bacteria found in the intestine in infectious diseases have been discharged through the wall of the intestine or through the liver. Most of the observations recorded concerning the transit of bacteria through the intestinal wall from the circulation have not been made so as to determine whether or not the escape is really through the intestinal mucosa or by way of the bile. Nevertheless, the frequency with which hemorrhages, necroses, inflammations, and ulcers of the intestinal mucous membrane occur in various infectious diseases makes it highly probable that pathogenic bacteria may be eliminated through this channel. Certain it is that the specific infectious bacteria, not only of diseases like typhoid fever, cholera, and tuberculosis, characterized by definite intestinal lesions, but of many other diseases, such as croupous pneumonia, septicæmia, pyæmia, are often found in the fæces.

Tubercle bacilli may be present in the milk of tuberculous cows even when there is no demonstrable tuberculosis of the udder. The statements as to the frequency of this occurrence vary. Ernst demonstrated by the microscope tubercle bacilli in the milk of 28.5 per cent. of the thirty-five tuberculous cows examined, and by inoculation experiments in 50 per cent. of fourteen cows. Bang by the inoculation test found tubercle bacilli in the milk of only nine out of sixty-three tuberculous cows without mammary tuberculosis. When the udder is tuberculous the bacilli are always in the milk.

Numerous observations have been made to determine whether or not the pyogenic cocci are excreted with the milk in puerperal infections, but since we now know that the staphylococcus albus is regularly, and the staphylococcus aureus is sometimes, present in the milk of healthy women, the demonstration of these cocci in the milk in cases of puerperal fever has lost much of its diagnostic significance. There is, however, reason to believe that, although the ordinary source of the staphylococci found in the milk is from the skin, they may be excreted through the gland from the blood in pyogenic infections. The presence of streptococci in the milk is more significant of such excretion than that of staphylococci. In several cases of puerperal fever streptococci have been found in the milk, although more frequently they are missed in this secretion under these circumstances. There is evidence that the pyogenic cocci causing mastitis may enter either from without through the lacteal ducts or may have been deposited from the circulating blood. Karlinski claims to have demonstrated that the staphylococcus aureus injected into the blood of rabbits may be excreted through the mammary gland.

Foà and Bordoni-Uffreduzzi and Bozzolo have found pneumococci in the milk of pregnant women affected with lobar pneumonia, and the former investigators demonstrated their presence in the milk of pregnant rabbits inoculated with this organism, and noted pneumococcus septicæmia in young rabbits which sucked the breast of their infected mothers.

The typhoid bacillus has been found exceptionally in the milk in cases

of typhoid fever. In experimental anthrax the specific bacillus appears in the milk only exceptionally.

Brunner found the staphylococcus albus, von Eiselsberg, Preto, and Tizzoni the staphylococcus aureus, in the sweat in cases of pyæmia. The detection of staphylococci, particularly of the staphylococcus albus, in the human sweat does not necessarily prove that they have been excreted through the sweat-glands from the blood, for even after the most thorough disinfection of the surface of the skin the white staphylococcus has not usually been destroyed in the deeper layers, as has already been explained in describing the bacteria of the skin. Still, it is probable that pyogenic cocci may be eliminated by the sweat-glands, for Brunner has shown that the staphylococcus aureus and the bacillus prodigiosus injected into the circulation of swine can be demonstrated in the sweat from the snout after administration of pilocarpine. He was also able to detect the anthrax bacillus in the sweat from the paw of an infected cat after stimulation of the sciatic nerve. He reports only three experiments, and it is desirable that more work should be done on this subject, as the frequency with which pathogenic bacteria may appear in the sweat in infectious diseases is of importance, especially with reference to possibilities of contagion and to measures of disinfection.

In Brunner's experiment with the bacillus prodigiosus this organism was found also in the saliva, and there are other observations which indicate the possibility of elimination of bacteria through the salivary glands.

Conditions favoring the Development of Surgical Infections.

There are various conditions, relating partly to the micro-organisms concerned and partly to the individual receiving the organisms, which are determining factors in causing infection. The factors pertaining to the individual are usually grouped under the vague but indispensable term "predisposition."

Dosage and Virulence of Infecting Bacteria.—In the case of some pathogenic bacteria a single bacterial cell may be capable of infecting a highly susceptible animal, whereas with a less susceptible animal a large number of the same kind of bacteria may be required. In his interesting studies on the relation of the dosage of bacteria to infection Watson Cheyne[1] showed that whereas a single virulent bacillus of rabbit septicæmia was capable of causing fatal septicæmia in the highly susceptible rabbit, in the less susceptible guinea-pig the fatal dose was 300,000 bacilli and upward; between 10,000 and 300,000 bacilli produced abscesses, and smaller doses were without effect. In a mouse a single bacillus of mouse septicæmia, and in a guinea-pig a single virulent anthrax bacillus, were capable of producing fatal infection, whereas in rabbits and sheep a considerable quantity of the anthrax bacilli was required to kill the animals.

Animals are in general insusceptible to small quantities of the pyogenic cocci, whether introduced subcutaneously or into the circulation. It generally takes several hundred thousand of the cocci to produce local abscesses by intravenous or subcutaneous injection. Man is more susceptible to these cocci.

[1] Watson Cheyne, *The British Medical Journal*, July 31, 1886.

This question of dosage is largely one of individual or racial susceptibility on the one hand, and of virulence of the micro-organisms on the other hand.

The kind of infection produced by some bacteria varies with the dose. It often happens that the inoculation of a very small number of certain pathogenic bacteria produces no effect, a larger number cause only a local abscess, and a still larger number cause fatal septicæmia. This is illustrated by the micrococcus lanceolatus, some varieties of the streptococcus pyogenes, and other pyogenic cocci.

We are familiar with varying degrees of virulence in the case of a large number of pathogenic bacteria. Influences known to be capable of affecting the vitality and the virulence of bacteria, such as sunlight, desiccation, saprophytic growth, association with other bacteria or their products, are widely operative in nature. The virulence of a micro-organism depends probably mainly upon its capacity to form toxic products, as it is by these products that bacteria chiefly produce their pathogenic effects.

Bacteria which enter the body associated with their toxic products are much better adapted to cause infection than when they enter deprived of these products. These toxic substances, by damaging immediately the cells and fluids which protect the body from infection, enable the invader to gain a foothold which it might otherwise not have secured. Vaillard claims that tetanus spores, deprived by heat or by washing of their toxines, are incapable of germinating in the animal body without the aid of accessory causes, such as the presence of other micro-organisms, dirt, other foreign substances, necrotic tissue, although the spores themselves are still alive and in suitable media capable of development. If, however, as is usual in our laboratory experiments, the spores or bacilli be inoculated with the toxin, which in most minute doses is of appalling potency, tetanus is sure to develop. In fact, our experimental tetanus is, as a rule, essentially a pure intoxication.

The varying results which follow the introduction into the body of pyogenic cocci derived from different sources depend doubtless in part upon whether these cocci enter the tissues already equipped with a reserve force of poisonous products or must begin the fight unarmed. The inoculation of infectious material coming directly from the human body, as from a case of puerperal peritonitis, and received perhaps only in a puncture or scratch of the skin, may manifest disastrous effects with which we are not familiar in inoculations with our artificial cultures of the pyogenic cocci obtained from the same source.

The micrococcus lanceolatus, the streptococcus pyogenes, and the pyogenic staphylococci are notable for the wide variations of their virulence. The lanceolate coccus quickly loses its virulence in artificial cultures.

The writer has reported observations as to the varying virulence of the staphylococcus aureus cultivated from different sources. Some broth cultures were fatal to rabbits within twenty-four to forty-eight hours when injected into the circulation in the dose of 0.1 c.c., and other cultures injected in the same way produced no apparent effect in the dose of 1.5 c.c. Between these extremes were cultures of all degrees of intermediate virulence. In the majority of cases 0.2 to 0.3 c.c. of fresh

bouillon cultures killed the animal within three to seven days after intravenous injection. The variations in virulence of the streptococcus pyogenes are even more striking. Pathogenic bacteria, especially pyogenic cocci, obtained from an infected individual are more likely to be highly virulent than when cultivated from other sources. There are, however, many exceptions to this general rule.

In various ways the weakened virulence of pathogenic bacteria may become augmented. Among the most important of those ways with which we are acquainted are repeated passage through the animal body, association with other bacteria or their products, and the addition of certain chemical substances.

The character of the infection varies often with the degree of virulence of the specific micro-organism. Bacterial species, which when highly virulent may kill quickly with septicæmia, may, with weakened virulence, require a much longer period to produce the same effects, or may give rise to only local inflammation without general infection. It is especially with bacteria of attenuated virulence that the matter of dosage may be a controlling factor.

The varying virulence of the pyogenic cocci is one of the factors in the explanation of the remarkably diverse effects which these organisms are capable of producing in the animal body. These cocci may under different circumstances cause all grades and kinds of inflammation, serous, fibrinous, suppurative; they may cause localized inflammations and general infections. But there are other circumstances besides the degree of virulence which control these varying results. Equally important, in many cases more important, controlling factors are the manner of invasion of the micro-organism and various local and general predisposing conditions.

In fact, there is no definite and constant relation between the character and the severity of an infection produced in man by pyogenic cocci and the virulence of the cocci cultivated from the case. From the gravest septicæmias cocci of slight degrees of virulence may be cultivated, and from a simple epidermal pustule cocci of high virulence, as tested upon animals. There is reason to believe that the virulence of the micro-organisms may be modified during the course of an infection, so that we cannot necessarily draw conclusions as to the primary virulence of the organism at the time of its invasion from the virulence noted in cultures from later stages of the disease.

Bacterial Association.—Bacteria are not usually found in the external world under natural conditions in pure culture, but they are mixed together. Mixed infections are common in human beings. In suppurating wounds we usually find more than one bacterial species. It is of importance to learn the relations of these bacterial associations to infection. We are at present only imperfectly informed as to these relations, but we know that they are often of great significance. Only the more salient points which directly bear upon our theme can be considered here.

The association of one bacterial species with another may be without influence upon the development or the properties of either, or one species may be favorable to the growth or enhance the virulence of another, or one species may be antagonistic to another or in various ways modify its

characters. Bacteria exert their influence on each other in large part through their chemical products, and it is often possible to bring about modifications of character by exposing one species to the action of the chemical products of another species.

The pathogenic, the chromogenic, the fermentative, and the other vital manifestations of bacteria may be influenced by their combination with each other. The bacillus pyocyaneus may lose its power of producing pigment when combined with certain other bacteria (Mühsam and Schimmelbusch). In mixed cultures of certain bacteria chemical products may be formed and fermentations produced which neither of the species in the culture is capable of producing by itself alone (Nencki, Burri, and Stutzer). In mixed cultures of two pathogenic bacteria a larger amount of the toxic products of one or both may be formed than either produces when in pure culture (von Schreider).

The effects following the concurrent inoculation of two kinds of bacteria vary. The association may be without influence as regards infection. The result may be that the development of a deadly species of bacterium is checked by the introduction of another species which is relatively harmless. The only striking instance of this is the effect of the inoculation of the streptococcus of erysipelas, the bacillus of Friedländer, and of several other species of bacteria simultaneously with or shortly before or after inoculation with the anthrax bacillus. These bacteria or their products introduced into the body are capable of preventing the developing of the anthrax bacillus and of rescuing the animal from certain death (Emmerich and others). Various explanations of this effect are given by different writers. The effect is probably referable not so much to a direct antagonism of one species to the other as to an augmentation of the antibacterial properties of the cells, which, according to von Dungern and Metschnikoff, is manifested by increased phagocytic activity of the leucocytes. Bacteria in general which cause suppuration may thereby prevent the development of the anthrax bacillus in the focus of suppuration.

More frequently the concurrent inoculation of two species of bacteria increases the danger to the animal from one or both. A combination of two species, each in itself harmless, may prove fatal to the animal (Roger). A bacterium of attenuated virulence may become augmented in virulence by inoculation in combination with another species which need not necessarily be itself pathogenic, or sometimes simply in combination with the chemical products of another species. The following are examples of the exaltation of the virulence or of the pathogenic effects of one kind of bacterium by combined inoculation with another kind or its products: that of the micrococcus lanceolatus by combination with the proteus vulgaris, the anthrax bacillus, or the diphtheria bacillus (Monti, Pane, Mühlmann, Mya); the streptococcus pyogenes with the proteus vulgaris, bacillus prodigiosus, bacillus coli communis (Klein, Monod, and Macaigne); the pyogenic staphylococci with the bacillus prodigiosus or its products and other bacterial products (Grawitz and De Bary and others); the diphtheria bacillus with the streptococcus pyogenes or its products (Roux and Yersin and others); the typhoid bacillus with the streptococcus pyogenes, colon bacillus, and proteus, or their products (Vincent, Sanarelli); the bacillus coli communis with the typhoid bacil-

lus and the streptococcus pyogenes (Pisenti and Bianchi-Mariotti); the bacillus of symptomatic anthrax with the bacillus prodigiosus (Roger). Mention has already been made of the pathological importance of the association of the tetanus bacillus with other bacteria. Of especial interest are the experiments of Prudden demonstrating that the intratracheal injection of cultures of the streptococcus pyogenes in tuberculous rabbits leads to the formation of regular phthisical cavities in the lungs—a result which is not obtained by the inoculation of either microorganism alone. Bernheim has demonstrated that the diphtheria bacillus grows more luxuriantly and with a larger production of toxin in the filtrate of streptococcus bouillon cultures than in ordinary bouillon.

A most important group of infections, many of them of surgical importance, is furnished by the secondary invasion of pathogenic bacteria in the course of various infectious diseases, such as typhoid fever, tuberculosis, diphtheria, scarlet fever, small-pox, and other exanthematous fevers. The streptococcus pyogenes is more frequently the infectious agent in these secondary infections than any other organism, but the other pyogenic cocci are not uncommonly concerned. The primary infection increases susceptibility to these common pyogenic cocci, which often find the way open for their invasion by some lesion of an exposed surface of the body. It is also very probable that the primary infection may bring about conditions which enhance the virulence of the bacteria concerned in the secondary infection. Although it is not necessary to suppose that these common secondary invaders are always derived from those which are present in health upon exposed mucous membranes, nevertheless they doubtless often have this origin. Pyogenic cocci obtained from these secondary infections are usually, although by no means always, more virulent than when cultivated from the healthy mucous membranes.

Of especial frequency and importance among the mixed and secondary infections here in consideration is the association of the tubercle bacillus with the streptococcus pyogenes, the typhoid bacillus with pyogenic cocci, and the diphtheria bacillus with streptococci.

The characters of the various mixed infections are probably determined less by a direct influence of one bacterial species or its products upon another, although this factor appears in some cases to be an important one, than by the action exerted by one or both species upon the resisting powers of the fluids and cells of the body.

Immunity and Predisposition.—In no class of infectious diseases is the influence of predisposition as an etiological factor more apparent than in many of the surgical infections. If a wound could be kept entirely free from pathogenic bacteria, it would not suppurate, no matter how favorable in other respects the local and general conditions for infection might be. The occurrence of suppuration in human beings from sterile chemical irritants is so exceptional that we need not consider this form of suppuration here. It is not, however, possible in all, or even in most, cases to keep bacteria wholly out of a wound. The examination of so-called aseptic wounds shows with great frequency the presence of bacteria, and notably of the white skin-coccus, but also sometimes of other pyogenic cocci, including the staphylococcus aureus. Although the cocci found under these circumstances are usually of weakened viru-

lence, nevertheless, as shown by Büdinger and others, they are of some virulence, and may be decidedly virulent. The frequency with which pyogenic bacteria enter wounds is by no means expressed by the frequency with which wounds suppurate. Every surgeon knows that in certain persons and in certain conditions of the body a wound is much more likely to suppurate than in others, although the same precautions are taken to guard against the entrance of micro-organisms. It is therefore a matter of prime importance, no less of practical than of scientific interest, to learn, so far as we may, what are the conditions which predispose an individual to infection. Unfortunately, we are at present only imperfectly informed as to many of these conditions.

Predisposition is of most importance in the etiology of those infectious diseases which are caused by micro-organisms to which the individual or the species is not in the highest degree susceptible. The pyogenic cocci, in general, belong to this group of micro-organisms, although they may exist in a condition of such exalted virulence that predisposition becomes a factor of no significance.

The degree of susceptibility to a specific micro-organism influences not only the capacity to acquire the infection, but also the course, severity, and character of the infection. In an individual of great susceptibility a micro-organism of attenuated virulence may produce effects which in a relatively insusceptible person can be accomplished only by a highly virulent micro-organism of the same species.

The astonishing variety of affections which may under different circumstances be caused by pyogenic cocci, from a simple epidermal pustule to the gravest septicæmia and pyæmia, from a serous to a suppurative inflammation, are to be explained in part by variations in the local or general susceptibility of the individual, although, as already explained, other factors, such as the degree of virulence of the organism, the manner of invasion, and the number of organisms introduced, are also important. We possess abundant experimental evidence of the fact that in the relatively insusceptible many pathogenic bacteria remain localized, causing inflammation, whereas the same bacteria in the highly susceptible invade the blood and internal organs, causing general septicæmia.

Immunity.—Our comprehension of the nature and importance of predisposition as a factor in the causation of infectious diseases has been facilitated by the increase of our knowledge concerning the factors upon which immunity from the invasion and multiplication of bacteria depends; but our understanding of the nature of immunity is still most incomplete. It is not necessary for our purposes in this connection to enter into a detailed consideration of the various doctrines of immunity, important as are the results of recent investigations upon this subject. It will suffice to state briefly the more important facts and hypotheses so far as they bear upon the question now under consideration.[1]

We distinguish natural or hereditary immunity from acquired immunity. Immunity may be acquired by recovery from an attack of a specific infectious disease, or may be artificially produced by vaccination with the specific micro-organism or its products, or by the injection of the

[1] The following statements concerning immunity are taken chiefly from the fuller article on this subject by the writer in Pepper's *Text-Book of the Theory and Practice of Medicine by American Teachers*, vol. ii., Philadelphia, 1894.

blood-serum or other fluids from individuals rendered artificially immune.

It is certain that the various kinds of immunity do not all depend upon the same causes. The leading theories of immunity may be brought into two classes—one which attributes immunity to the direct and active intervention of the living cells of the body, and the other which explains immunity by the properties of the extra-cellular fluids. In the last analysis these properties of the body fluids must depend upon the activities of cells, so that we must have recourse either directly or indirectly to cellular functions in any adequate explanation of immunity.

The leading representative of the cellular theories is the phagocytic theory, so elaborately and charmingly developed by Metschnikoff. This supposes that immunity depends upon the seizure of invading micro-organisms by amœboid cells, chiefly leucocytes and other mesodermic cells, and the subsequent destruction of these organisms in the interior of the cells. According to this view the leucocytes are charged with the defence of the body and engage in a veritable conflict with the parasites. The significance of inflammation, according to Metschnikoff, is to bring the leucocytes to the seat of danger, to which they are attracted by the positively chemotactic substances furnished by the micro-organisms. Immunity is acquired when the phagocytes have gained tolerance of the poisons of the specific micro-organism and are no longer repelled by them.

There exists in a very large number of cases unquestionably a parallelism between phagocytosis and immunity, but the action of phagocytosis is by no means always apparent. We know that micro-organisms may be destroyed by extra-cellular agencies as well as within the cells, and it is a fair question whether the micro-organisms before their reception by cells have not already been damaged by these other agencies. It is true that Metschnikoff has proven that phagocytes may take up living and virulent bacteria, and that these bacteria may degenerate and die in the interior of cells, but he has not shown that, as a rule, bacteria when taken up by cells have suffered no injury from extra-cellular agencies. We possess direct observations which prove that bacteria introduced into the body may degenerate and die not only within cells, but also outside of them in the humors.

The humoral theories of natural immunity have been based largely upon the demonstration by Nuttall, Buchner, and others of the bactericidal properties of the blood and other fluids of the body. Buchner has given the name of "alexins," and Hankin that of "defensive proteids," to these bactericidal substances. The bactericidal alexins are believed by Kossell and Vaughan to be nucleins or nucleinic acid. Their action is not exerted equally upon all bacteria, and there is often no parallelism between the presence of this bactericidal property in the blood of the normal animal and the insusceptibility of the animal to a given micro-organism. The important observation has been made, however, that as the result of the introduction of certain micro-organisms the body fluids may acquire bactericidal properties as regards the organism introduced.

The search for the origin of the alexins has led to the view that they

are derived directly from the cells, and particularly from the leucocytes. This has led to a partial reconciliation between the phagocytic and the most prominent humoral theories of immunity. The leucocytes and other cells are, indeed, the defenders of the body against intruding micro-organisms. They furnish the alexins, the weapons of attack. Where they accumulate the defensive material is concentrated, but it is not necessary that the bacteria should be actually incorporated in the body of the cells, although the germicidal properties may be more intense within than without the cells. Such is the explanation of natural immunity now adopted by Buchner and many others.

There is a kind of acquired immunity which is not known to have a parallel in forms of natural immunity. This is the so-called antitoxic immunity. Here, as the result of vaccination with the specific micro-organism or its products, the blood and fluids of the immunized animal have acquired the property of neutralizing the poison formed by the specific organism from which the individual has been immunized. The principles of antitoxic immunity have been worked out for the toxic infections, tetanus and diphtheria. The same principle doubtless holds good for acquired immunity from some other diseases, but for how large a number we cannot say. A most important characteristic of this antitoxic immunity is that by successive injections of increasing amounts of the poisonous substances into the animal the antitoxic or immunizing power of the fluids can be augmented to an astounding degree. It is in this way that the antitoxic power of the fluids may be rendered sufficiently high to exert curative effects when injected after the reception of the specific micro-organism or its products. This so-called serum-therapy has thus far been applied with beneficial results only to cases of tetanus and of diphtheria, and, as regards human beings, it is more efficient in diphtheria than in tetanus.

Local Predisposition.—The term "predisposition" is often used in a loose sense to designate all sorts of conditions which increase the chances of infection, or which augment susceptibility to infection, or which influence the localization, duration, character, or severity of infections. A name which is used to refer to conditions belonging to such different categories, having often nothing in common, is of course objectionable, but common usage sanctions the term, and there appears to be no better one under which to include the various points here to be considered.

We distinguish racial and individual predisposition, inherited and acquired predisposition, local and general predisposition.

Instances abound of differences in susceptibility to infectious diseases between different species of animals, and there are differences also between different races of men; but the most important kind of predisposition, as regards those surgical infections which we are here considering, is individual predisposition.

This individual predisposition may be either inherited or acquired. It may pertain only to one part or to certain parts of the body, or it may belong to the body as a whole. We cannot in many instances determine whether the predisposition is local or general, and, indeed, it is often impossible to draw any sharp dividing-line between local and general predisposition.

Local predisposition may be limited to one or more of the portals of entry for micro-organisms, or it may exist at some point within the body, constituting a so-called locus minoris resistentiæ.

We shall consider first predisposing causes of infection at the portals of entry. We shall have in view under this heading more particularly causes which act locally, but it is to be understood that general predisposing factors to be described later may produce local predisposition.

Under the heading of "Inflammation produced by Bacteria" Dr. Councilman in the preceding article has described the influence upon pyogenic infections of many local predisposing factors, such as the character of the tissue invaded, local anæmia, passive hyperæmia, the withdrawal of nerve-impulses from a part, rapidity of absorption, the introduction of chemical bacterial products, the presence of foreign bodies, previous attacks of inflammation; and the reader is referred to Dr. Councilman's article for these points. It has there been made clear that any interference with the integrity of the tissues and of the local blood- and lymph-circulation is likely to render them more susceptible to pyogenic agents, and to influence unfavorably the character and course of a subsequent inflammation. Wounds through a thick layer of adipose tissue or cicatricial tissue or other poorly-vascularized parts are less able to resist the action of pyogenic bacteria than wounds of such vascular parts as the face.

To the predisposing conditions enumerated may be added œdema of the tissues. How important this is may be inferred from the frequency with which erysipelas and suppuration follow so slight an injury as puncture of an œdematous scrotum or leg. Büdinger found that pyogenic cocci so weakened in virulence as to produce no effect when inoculated into the normal ear of a rabbit set up local suppuration when inoculated into an ear rendered hyperæmic and œdematous by temporary application of a rubber band around the root of the ear.

The withdrawal of nerve-impulses from a part may increase its liability to infection. The factors here concerned are various, the most apparent ones being anæsthesia, disturbances in the lymphatic and blood circulation, and nutritive changes. The question as to the existence of special trophic nerves, the interference with whose function predisposes the part to infectious inflammations, has been considered by Dr. Councilman. In a personal communication Dr. Weir Mitchell has kindly favored the writer with the following expression of his views on this point: "I think it true that the withdrawal of nerve-impulses from a part favors infection; that the withdrawal of nerve-influence with partial failure of circulation in some cases of injury still further favors infection; that there is a condition of traumatic nerve-irritation which, probably by its abnormal influence on nutrition, favors infection. A partial injury of a nerve sets up local neuritis and may bring on ulcers of a peculiar character.[1] It seems to me that if we injure a nerve-supply, the changes in muscular and nerve conditions which immediately take place would favor such chemical changes in the tissues as to make them more or less susceptible to infection."

Abnormalities in the secretions on exposed mucous surfaces and in

[1] Interesting examples of such ulcers are here cited by Dr. Mitchell from the forthcoming book of his son, Dr. John H. Mitchell, on *Nerve-injuries and their Remote Results.*

the glands communicating with them may be a local predisposing cause of infection. Obstruction to the outflow of secretions, and the presence of calculi or foreign bodies in cavities or glandular ducts opening upon exposed surfaces are important predisposing causes of infection, as is exemplified by inflammations of the vermiform appendix, renal pelvis, urinary and gall-bladders, urethra, the biliary, pancreatic, and salivary ducts.

In general, all traumatic and pathological lesions of exposed surfaces of the body, such as wounds, hemorrhages, necroses, waxy degeneration, inflammation, ulcers, stricture, strangulation, perforation, increase in greater or less degree the opportunities for the entrance, lodgement, and multiplication of pyogenic and other micro-organisms.

A suppurating surface, however, offers considerable resistance to the growth and invasion into the body of most pathogenic bacteria. Pus is endowed with marked bactericidal properties, both in its corpuscular elements and its fluid constituents, and the opportunities for absorption from a suppurating surface are much less favorable than from a fresh wound. Sestini found that the bacilli of anthrax and of rabbit septicæmia when applied to a suppurating wound of the rabbit's skin produced no infection, although they readily did so when introduced into a fresh wound. The existence of suppuration, however, lowers the general resistance of the body to bacteria.

The various lesions which interrupt the continuity and integrity of the exposed surfaces of the body become most dangerous channels of infection when the general resistance of the body to infectious agents is lowered, as in various infectious fevers and constitutional diseases.

Experiments and clinical observations have been made with reference to the amount of damage to the intestinal coats which is requisite in order to permit the passage of bacteria from the intestinal canal into the peritoneal cavity. Most observers have found the fluid in the sac of a strangulated intestinal hernia free from bacteria in the great majority of cases. Garré found bacteria only once in eight cases; Rovsing did not find them at all in five cases; nor did Ziegler in five cases; Tavel and Lanz obtained a positive result only twice in seventeen cases of intestinal strangulation; in two out of three omental strangulations they found bacteria; Tietze found bacteria in four out of nine cases, with the possibility that in some of the four cases they were accidentally introduced from without. Sanguineous hernial fluids with bloody infiltration of the intestinal coats were observed without the presence of bacteria, and even the fluid in sacs containing necrotic intestine did not always contain bacteria. The presence of fibrinous peritonitis over strangulated intestine does not necessarily involve the presence of bacteria in the exudate, as this form of peritonitis may be caused by the absorption of the chemical products of bacteria from the intestine (chemical peritonitis). Definite relations between the condition of the intestine and the presence of bacteria in the hernial sac were not observed.

For some at present inexplicable reason Boennecken found bacteria in the sacs of all of the eight strangulated hernias which he examined.

Arndt has shown by experiments on rabbits that bacteria may pass through the strangulated intestinal wall without the existence of necrosis of the intestine, and when the condition of the intestine is such that it

quickly returns to the normal state upon relief from the strangulation. The presence of bacteria in the hernial fluid does not necessarily involve the development of peritonitis. The conditions which permit bacteria to wander from the intestine through its wall into the peritoneal cavity have not as yet been made clear. Tietze has shown that the fluid from a hernial sac possesses marked bactericidal power over some intestinal bacteria.[1]

The entrance of the colon bacillus into the circulation is usually, in our experience, associated with some lesion of the intestinal mucosa, although this is not invariably the case. Absorption of pathogenic bacteria, particularly the pyogenic cocci, from the diseased intestinal mucosa is a fruitful source of various infections of internal parts, and many cases regarded as cryptogenetic septico-pyæmia have this origin.

The importance of accessory and predisposing causes of inflammations due to bacteria is nowhere better illustrated than in the etiology of peritonitis, as has been set forth by Dr. Councilman on page 180. There are two principal classes of predisposing causes of peritonitis—namely, substances which damage the endothelial cells of the peritoneum, and solid, unabsorbable substances.

Of especial importance to the surgeon is a knowledge of the local and general predisposing causes of the infection of wounds. The general predisposing factors we shall consider later. From what has already been said, it is apparent that while the surgeon should use every effort to keep bacteria out of a wound, he should refrain so far as possible from doing anything which interferes with the power of the fluids and cells to overcome invading micro-organisms.

Among the local conditions[2] which have been found favorable to the growth in wounds of bacteria which otherwise might be disposed of by the tissues and animal fluids without harm may be mentioned strangulation of masses of tissue by ligatures; the presence of foreign bodies, such as drainage-tubes and coarse ligatures; interference with the circulation and absorption and the vitality of tissues resulting from undue pressure or tension; dead spaces; accumulation of the fluid and solid discharges from a wound, especially when associated with tension; necrosis and degeneration of tissues caused by the contact of strong chemical irritants. If it were within the power of the surgeon to keep bacteria entirely out of wounds or to destroy them without damage to the tissues after they enter, the conditions just mentioned could not by themselves alone cause infection, but this power he does not at present possess. The so-called aseptic wound of the surgeon is not usually aseptic in the bacteriological sense; that is, free from bacteria.

The following objections to the insertion of drainage-tubes into wounds have been elsewhere formulated by the writer:[3] *First.* They

[illegible] experiments and observations thus far [illegible]; Tavel and Lanz, "Ueber die [illegible] *Inaug. d. Schweiz.* Basle [illegible] Drummond einen eingeklemmter Brüche [illegible] Vol. 49.

[illegible] Dr. William [illegible] and numerous suggestions as [illegible] the infection of wounds. [illegible] Surgery," *The Maryland*

tend to remove bacteria which may get into a wound from the direct bactericidal influence of the cells and animal juices. *Second.* Bacteria may travel by continuous growth or in other ways down the sides of a drainage-tube, and so penetrate into a wound which they otherwise would not enter. We have repeatedly been able to demonstrate this mode of entrance into a wound of the white staphylococcus found so commonly in the epidermis. The danger of leaving any part of a drainage-tube exposed to the air is too evident to require mention. *Third.* The changing of dressings necessitated by the presence of drainage-tubes increases in proportion to its frequency the chances of accidental infection. *Fourth.* The drainage-tube keeps asunder tissues which might otherwise immediately unite. *Fifth.* Its presence as a foreign body is an irritant and increases exudation. *Sixth.* The withdrawal of tubes left any considerable time in wounds breaks up forming granulations, and thus both prolongs the process of repair and opens the way for infection. Granulation tissue is an obstacle to the invasion of pathogenic bacteria from the surface, as has been proven by experiment. *Seventh.* After removal of the tube there is left a tract prone to suppurate and often slow in healing.

The advantage from the employment of drainage-tubes or other drainage material is, of course, the removal of secretions, and this indication becomes an urgent one if the cavity with which the tube communicates is infected and suppurates. In a given case the surgeon must weigh the advantages and the disadvantages and act according to his judgment. The practice of most surgeons at the present time of restricting within much narrower limits than formerly the use of drainage-tubes, and of discarding them for all wounds which offer a fair prospect of primary union, is a distinct advance in the technique of antiseptic surgery.

The presence of blood in a wound is not itself to be desired, and modern surgeons justly lay stress upon prompt and careful hæmostasis in surgical operations. Blood in a wound is not, however, so dangerous a thing as some have supposed it to be, and where for the obliteration of cavities in a wound the choice lies between a blood-clot and the introduction of foreign substances, or the exercise of undue tension by sutures, or the application of a very large number of sutures, or forcible pressure, it is, as a rule, better to take the chances that the spaces will fill with blood (Halsted). Blood possesses bactericidal properties, and experiments made by the writer and Howard[1] showed that virulent pyogenic staphylococci injected into blood-clots which had been allowed to fill wound-cavities did not multiply and occasioned no suppuration. John Hunter was fond of dwelling upon what he called the vitality of blood, and John Chiene has directed attention anew to similar views. Schede brought prominently to the notice of surgeons the value of the blood-clot in the healing of a certain class of wounds, and Halsted[2] further extended the field of its application. The unintended presence of blood in a wound by occasioning undue tension and in other ways may be a dangerous thing, and is something very different from the purposeful application of

[1] Welch, "Conditions underlying the Infection of Wounds," *Transactions of the Second Congress of American Physicians and Surgeons*, vol. ii., 1891.

[2] Halsted, "The Treatment of Wounds with especial reference to the Value of the Blood-clot in the Management of Dead Spaces," *The Johns Hopkins Hospital Reports*, vol. ii. No. 5.

the method of healing by so-called organization of blood-coagula. It is of the first importance to prevent so far as possible all tension in a wound.

Undue stress is sometimes laid upon artificial devices to close the so-called dead spaces of a wound. These spaces when not drained, nor stuffed with foreign substances, nor obliterated by sutures or pressure, nor permitted to fill with blood, do not, unless very large, remain empty spaces. They quickly fill with exudations of fluids and cells, and these fluids and cells possess antibacterial properties as well as blood. For cavities with unyielding walls, such as those in bone, the blood-clot method of treatment has been found especially useful.

Surgeons are not agreed as to the value of the application of antiseptic fluids and substances to fresh wounds. There has been in recent years, under the name of aseptic surgery, a general tendency to consider them useless or harmful, but some surgeons still advocate the antiseptic irrigation of fresh wounds. The question is one which can be decided only by clinical experience. The experimental data bearing upon the question are the only ones appropriate to consider here.

The principal objections urged against the employment of the application of such disinfectants as corrosive sublimate and carbolic acid to fresh wounds are—*first*, that they accomplish little or nothing in the way of destroying bacteria which may have entered the wound; and, *second*, that they cause necrosis or other impairment of the tissues, and thereby weaken or abolish the antibacterial properties of the tissues, and thus predispose to infection.

The conditions for the destruction of bacteria by chemical disinfectants in the fluids and tissues of the animal body, even when the bacteria are only upon an exposed surface, are most unfavorable as compared with those in experiments with the same agents in test-tubes. The experiments of Schimmelbusch, already cited, do not, as he seems to suppose, demonstrate the uselessness of antiseptic applications to wounds in general. He found that the fatal infection of mice with the bacillus anthracis and that of rabbits with the bacilli of rabbit septicæmia, introduced in large number into fresh wounds, could not be prevented by the irrigation of the wound with corrosive sublimate (1 : 1000) or carbolic acid (5 per cent.) or other antiseptics. But some of the bacteria thus introduced, as has already been explained, are immediately or very soon absorbed from fresh wounds, and if one bacillus or a very few bacilli of the kind used by Schimmelbusch were thus absorbed, the death of the animal was sure to follow; whereas a similar absorption of a few ordinary pyogenic cocci is usually without significance. It is evident that these experiments are not conclusive as to the influence of antiseptics upon bacteria which remain in the wound, and are not applicable to the ordinary conditions of wound-infection during a surgical operation.

Henle[1] in his experiments conformed more closely to conditions of wound-infection in man. He found that in wounds of the rabbit's ear inoculated with streptococcus pus the streptococci remained in the wound for six hours, after which the cocci began to occupy the neighboring lymph-spaces. He found that regularly up to the end of the second hour a complete disinfection of the wound with sublimate (1 : 1000) or

[1] Henle, *Centralblatt für Chirurgie*, 1894, No. 30, *Beilage*.

carbolic acid (4 per cent.) could be attained, and that even after six hours the disinfection sometimes prevented the development of the disease, and, if not completely successful, rendered the subsequent infection milder than in the inoculated control ear which was not disinfected.

Löffler has shown by his careful tests of the action of various antiseptic substances upon diphtheritic throats that it is possible to destroy the superficial bacteria by antiseptics without serious injury to the tissues. It is possible that disinfectants, without actually killing bacteria, may restrain their power of development or weaken their virulence.

Messner[1] experimented by inoculating fresh wounds of rabbits with pus or with cultures containing pyogenic cocci, which caused progressive phlegmonous inflammation with fatal termination. He found that, with one exception, all of the ten wounds inoculated with the cocci, and then irrigated with sterile salt-solution and treated aseptically, suppurated, with the development of progressive phlegmons which killed the animal within two weeks. On the other hand, all of the ten wounds, with one exception, similarly inoculated and treated antiseptically with lysol or 3 per cent. carbolic-acid solution, healed and the animals survived. Two of the wounds treated antiseptically healed without suppuration; the remaining eight suppurated, showing that the cocci had not actually been destroyed, but the process remained localized. Pus from the wounds treated aseptically preserved its virulence, whereas pus from the wounds treated antiseptically was devoid of virulence when inoculated *into* animals.

Hermann and others have shown that if carbolic acid, corrosive sublimate, and various other chemical irritants be injected subcutaneously into the tissues and soon afterward pyogenic micro-organisms be injected into the same locality, the formation of an abscess is much more likely to follow than when the bacteria are injected into the healthy tissues. But, as Messner has shown, a similar favoring influence upon the development of suppuration under these circumstances is exerted by the injection of common salt-solution into the subcutaneous tissues. These experiments are not applicable to the conditions existing in an open wound, but they confirm clinical observations as to the great danger of introducing into the subcutaneous tissues of man, with a hypodermic syringe, fluids containing pyogenic bacteria.

Unquestionably, the presence of necroses, such as may be produced by strong chemical disinfectants, predisposes to pyogenic infection. In some situations, as in a closed cavity like the peritoneal, the presence of even superficial necroses, which may affect only the endothelial cells, is an important predisposing cause of infection, but only experience can decide whether such slight superficial necrosis or other injury which the ordinary antiseptics may produce in an external wound is in itself an important predisposing factor in the pyogenic infection of wounds, or even if a predisposing factor is not more than counterbalanced by beneficial influences exerted by the application of antiseptics. Messner has reported experiments on rabbits which seem to show that the irrigation of fresh wounds with 3 per cent. carbolic-acid solution does not lessen the vital resistance of the tissues in a wound to subsequent inoculation with pyogenic cocci.

[1] Messner, *Ibid.*

Experiments upon animals, therefore, favor rather than oppose the antiseptic treatment of wounds, as distinguished from so-called asepsis.

We turn now to the consideration of local predisposition existing at some point within the body, the so-called locus minoris resistentiæ. After the infectious agents have passed through the portal of entry and entered the general circulation they may find local conditions favoring their lodgement and development. Without such local predisposition they are often incapable of doing any harm.

Injury, inflammation, and other pre-existing disease of an internal part are important and common conditions favoring the lodgement and growth of micro-organisms. The classical experiment of Chauveau many years ago demonstrated the predisposition of injured internal parts to infection. He twisted off without rupture of the skin one of the testicles of a young ram from its vascular connections (bistournage), and observed that when he had injected shortly before the operation putrid fluid containing micro-organisms directly into the circulation the injured testicle became the seat of septic gangrene, while without such injection the testicle became necrotic and was absorbed without becoming infected.

The experiments of Rosenbach, Orth and Wyssokowitch, Prudden, and others have shown that bacteria do not readily become attached to the smooth surface of the heart-valves, but that pyogenic cocci readily adhere and set up septic endocarditis when the valves have been previously torn by a sterile probe passed down the carotid artery. The predisposition of injured joints and bones to the settlement of pyogenic cocci and of tubercle bacilli is established both by clinical and experimental observations. Pyogenic cocci often invade foci of disease caused primarily by other organisms, as is exemplified in tuberculous and gonorrhœal arthritis, actinomycosis, echinococcus cysts, amœbic abscesses of the liver, etc. In some situations, particularly in the kidney and urinary tract, the colon bacillus often settles in pre-existing foci of disease. The anæmic and dry condition of the lung induced by pulmonary stenosis favors the development of pulmonary tuberculosis. The hyperæmic and moist condition associated with mitral regurgitation is comparatively unfavorable to such development, although by no means excluding this disease. Pyogenic cocci not infrequently settle in the joint-lesions of locomotor ataxia and cause suppuration.

The existence of a diseased or injured part within the body by no means involves, of necessity, the localization therein of infectious processes which may be caused by pathogenic micro-organisms in the circulation. The damaged part may be spared and an apparently healthy part attacked. The endeavor to obtain experimentally in animals the localization of suppuration in a fractured bone or other injured or diseased part by pyogenic cocci injected into the circulation often fails, and in the hands of Rinne failed so regularly that he opposes, although without sufficient reason, the whole doctrine of locus minoris resistentiæ. By a different line of experimentation Gottstein came to the same conclusion as Rinne.

We are undoubtedly able in some cases to explain the localization of an infection by such apparent local predisposing causes as those which have been mentioned, but in many, indeed in the majority of, instances of localized infections of internal parts we are unable to give any satis-

factory explanation of the localization. We know that many pathogenic micro-organisms have a decided preference for certain organs and tissues. The injection of the staphylococcus aureus into the circulation of rabbits does not lead to the formation of abscesses in all parts of the body, although the cocci must be carried by the blood-current everywhere. The abscesses are found most frequently in the kidneys and myocardium, sometimes in the muscles elsewhere, and in young rabbits often in the bone-marrow and joints. To say that the tissues in one part of the body offer better conditions for the growth of the micro-organisms than in other parts is only another way of saying that the organisms produce disease in one part and not in another. Such phrases offer no real explanation unless the nature of these better conditions can be defined.

Sometimes we can explain the localization by the manner of reception of the virus, the vascular relation of the part to infected areas, the size and number of the capillaries, the velocity of the circulation, and the readiness with which foreign particles are filtered out. We know that fine particles are deposited from the lymphatic current in the lymph-glands, and from the blood-circulation chiefly in the spleen, marrow of the bones, liver, and lymph-glands. More often we are unable to give any adequate explanation of the localization of an infectious process in internal parts of the body.

General Predisposition.—Under this heading we shall consider predisposing causes which act more or less generally upon the whole body. The effect of such causes may be to increase the susceptibility of the whole body or only of particular parts of the body to infection. The factors here concerned are for the most part less tangible than the local causes of predisposition.

Organs and parts of the body may inherit special vulnerability to certain infections. Susceptibility to certain infectious diseases may be manifest in races and families. The negro race is less susceptible to yellow fever than the white. Algerian sheep are in large measure insusceptible to anthrax, which is very fatal to other sheep. Black rats are more resistant than gray, and gray rats more resistant than white, to anthrax (Müller).

Age influences predisposition, as regards some infectious diseases favorably, as regards others unfavorably. Wounds in children, as a rule, heal more quickly, and with less danger of suppuration should pyogenic bacteria enter, than in old people. Certain infectious diseases are most common in infancy, others in adolescence or in maturity or in old age. Osteomyelitis is much more common in children than in adults. This has been attributed to the predisposing influence of injuries to which children are more liable. Doubtless injuries enter into the causation as a predisposing factor, but it has been shown experimentally that there is a special susceptibility of the bone-marrow of young growing animals to infection by pyogenic cocci injected into the circulation (Rodet, Colzi, Courmont and Jaboulay, Lannelongue and Achard, Lexer). In laboratory experiments young animals, as a rule, are found to be more susceptible to most pathogenic bacteria than old ones. There is a special insusceptibility of sucklings during the first months of life to certain infectious diseases, such as mumps, measles, scarlet fever. As will be explained

later, the embryo possesses remarkable insusceptibility to some infections.

There is no evidence that there is any difference in predisposition to infection between males and females, except as regards infections directly related to sexual functions.

General anæmia, induced by loss of blood, has been shown experimentally to increase susceptibility to infection with various micro-organisms, including the pyogenic cocci, Friedländer's bacillus, and the anthrax bacillus (Rodet, Gärtner, Chauveau, and others). Operative and other wounds are more likely to suppurate when there has been much hemorrhage than when the loss of blood is slight. In general, impaired vitality and nutrition of the body may predispose to certain infections, including wound-infection. More or less plausible predisposing causes operating in this way are bad and insufficient food, overwork, depressing emotions, exposure to heat or cold, overcrowding, bad air, and, in general, insanitary surroundings and all conditions of misery.

A large number of experiments have been made upon animals to determine the influence of various factors in increasing susceptibility to infection. The results of these experiments are interesting and suggestive in many ways. Some of them evidently correspond to conditions observed in man, but it is to be remembered that without additional evidence we have no right to apply the results directly to human beings, or to any other bacteria or other animals than those experimented with. The more important results of these animal experiments are the following:

Prolonged narcosis may impair resistance to some pathogenic microorganisms. Klein and Coxwell made frogs and rats highly susceptible to anthrax by narcosis with ether and chloroform, and similar results have been obtained with curare, alcohol, chloral, morphine, and upon other animals and with other diseases. In speaking of the effect of anæsthetics in predisposing to wound-infection Roswell Park [1] says: "There is good reason to think that chloroform and ether administered for some time may produce such changes in the blood and tissues that vital processes of repair, cell-resistance, and chemotaxis may be so far interfered with as to facilitate subsequent infection."

Feser, Hankin, and Müller found that rats fed on bread are more susceptible to anthrax than those fed on meat. Müller observed the same degree of insusceptibility when the extractive substances from meat were fed.

Canalis and Morpurgo, and Sacchi rendered pigeons highly susceptible to anthrax by hunger, and Bouchard noted the lowering or disappearance of artificial immunity in rabbits from anthrax by starvation. Prolonged abstinence from water was observed by Pernice and Alessi to render relatively insusceptible animals more susceptible to anthrax. Charrin and Roger found in fatigue induced by working a treadwheel a factor which increased the susceptibility of rats to anthrax and symptomatic anthrax.

Various chemical substances introduced into the body may increase susceptibility to certain infections. Gottstein and Mya and Sanarelli have shown that poisons, such as chlorates, pyrogallic acid, pyridin,

[1] Park, *loc. cit.*

which destroy red blood-corpuscles, may render insusceptible animals highly susceptible to certain pathogenic micro-organisms, although hæmatolysis thus produced in the case of some animals and certain micro-organisms did not weaken natural immunity. Bonome found that hæmatolysis and hæmoglobinuria caused by injection of water into the circulation of rabbits lessened the bactericidal power of the blood as regards the staphylococcus aureus. By feeding white mice with phloridzin, which produces glycosuria, Leo rendered these animals highly susceptible to glanders, from which normally they are immune.

The most important class of experiments showing the predisposing influence of certain chemical substances upon infection are those in which various ferments and bacterial products have been used. In considering bacterial association (page 291) attention has already been called to the fact that the chemical products of some bacteria favor the development of infection with other bacteria. The susceptibility of an animal to infection with a specific micro-organism can often be increased by the preliminary or simultaneous injection of the products of the organism. It is not only the products of pathogenic bacteria which may thus increase susceptibility, but also those of certain saprophytic varieties, particularly of the ordinary putrefactive bacillus proteus. Nor is it necessary that the bacterial products in order to weaken resistance to infection should cause distinct toxic symptoms. We do not possess any satisfactory experimental evidence that the volatile and stinking products of putrefactive decomposition augment susceptibility to infection.

Park, Bouchard, and others lay much emphasis upon auto-intoxication from absorption of fermentative products in the stomach and intestine as a predisposing cause of infection, particularly with the pyogenic cocci. Neumann and Canon, in order to test the predisposing influence of absorption of fermentative products from the intestine, ligated aseptically the small intestine of rabbits near the ileo-cæcal valve and injected subcutaneously a streptococcus culture. The animals with intestinal obstruction, with few exceptions, died with streptococcus septicæmia, whereas the streptococci injected into normal rabbits produced only local inflammation at the point of injection. The ligation of the intestine close to the stomach was not followed by generalization of the streptococcus infection. So deadly an operation as ligation of the intestine introduces so many other factors than the possible absorption of poisonous intestinal products that these experiments cannot be considered to prove what they were intended to demonstrate. Extirpation of the kidneys, with subcutaneous injection of streptococci, also leads to general streptococcus infection.

That many acute and chronic diseases lower the resistance of the body to pathogenic micro-organisms has repeatedly been mentioned in the course of this article, and is universally admitted. The influence of certain infectious diseases in favoring the development of secondary and mixed infections has been sufficiently referred to.

Diabetes mellitus is well known to increase in a marked degree the susceptibility to infection, particularly with pyogenic cocci and the tubercle bacillus. Among other diseases characterized by lessened resistance to infection may be especially mentioned acute and chronic Bright's disease, arterio-sclerosis, cardiac disease, alcoholism, syphilis, rickets,

scurvy, leucocythæmia, Hodgkin's disease. All of these diseases are prone to lessen resistance to pyogenic cocci, and especially to the streptococcus pyogenes. A localized streptococcus infection is much more likely to become generalized when it develops in persons affected with any of these diseases than when it appears in a previously healthy person. Here also attention may be called to the terminal streptococcus septicæmias occurring in Bright's disease, heart disease, and various chronic diseases. They may not be distinguished by characteristic symptoms during life, and are to be ranked among such events as terminal pneumonia and dysentery. The portal of entry is most frequently the lungs, skin, and intestine.

Of 218 autopsies of chronic Bright's disease, general arterio-sclerosis, and chronic heart disease at the Johns Hopkins Hospital, in 154 there were definite infections. Of 32 cases of local streptococcus infection, excluding perforative peritonitis, tabulated from the autopsy records of the hospital by the writer, chronic nephritis, general arterio-sclerosis, or chronic heart disease was present in 18. In 11 out of 14 cases of general streptococcus infection one or more of these diseases was present. We have observed several cases of general streptococcus infection in leucocythæmia and Hodgkin's disease.

In a large number of cases we are able to find no explanation of the existence of individual predisposition.

In conceding to predisposition its full importance as a factor in the etiology of surgical infections, we are not to forget that pyogenic cocci occur of such virulence that they can readily overcome the natural resistance of the most insusceptible human being.

Fœtal Infection.

The embryo may be infected by transmission of the specific micro-organism with the ovum or semen. The only example of this germinal infection in which the conditions are thoroughly understood is pebrine of silkworms caused by sporozoa, which have been studied in all stages of transit through the ovum and spermatozoa to the infected offspring.

The only infectious disease of human beings which has been proven to be capable of conveyance to the offspring through the ovum or spermatozoa is syphilis. Congenital syphilis is usually due to germinal infection, and it may come from either a syphilitic father or a syphilitic mother.

Intra-uterine or placental infection of the fœtus may occur in many infectious diseases. Although the intact placenta is a perfect physiological filter, which does not permit the passage of inanimate particles from the blood of the mother to that of the fœtus, nevertheless pathogenic micro-organisms are capable of breaking through this barrier. The conditions which permit the passage of micro-organisms from mother to fœtus can sometimes be demonstrated in the form of definite lesions of the placenta, either pre-existing or caused by the specific micro-organisms or their products. Circulatory disturbances, hemorrhages, defects in the epithelium covering the chorion villi, areas of necrosis, and tubercles in the placenta have been observed with more or less frequency in cases of fœtal infection, but often no placental lesion could be detected.

In the later stages of pregnancy and during parturition the anatomical and physiological conditions would seem to be more favorable for the escape of micro-organisms from the mother's blood to the fœtus than in the early stages.

Some micro-organisms are much better adapted than others to pass through the placenta from mother to fœtus. In animals the bacilli of chicken cholera and of symptomatic anthrax and the pyogenic cocci frequently make this passage. Although there has been much controversy as to anthrax, it is now settled that anthrax bacilli often pass from mother to fœtus, but generally in such small numbers and without subsequent multiplication in the fœtus as to require special methods and careful search for their detection.

In human beings infection of the fœtus in utero has been observed in small-pox, measles, scarlet fever, relapsing fever, syphilis, tuberculosis, croupous pneumonia, typhoid fever, anthrax, and affections caused by pyogenic cocci. In general, such infection is exceptional, but in some diseases it is comparatively common. Surgical importance attaches to the fact that both experiments on animals and clinical observations show that the pyogenic cocci are frequently transmitted to the fœtus from an infected mother.

Developed tuberculosis in the new-born infant is extremely rare, although it has been observed, but this rarity does not prove that tubercle bacilli may not often be transmitted from mother to fœtus. It takes time and susceptibility for tubercle bacilli to produce recognizable lesions. Tubercle bacilli without developed tuberculosis have been repeatedly found in the fœtus of tuberculous mothers. Birch-Hirschfeld detected in a seven-months' fœtus, removed by Cæsarean section from a mother with acute miliary tuberculosis, tubercle bacilli both by microscopical examination and by inoculation of guinea-pigs. There were no tuberculous lesions in the fœtus. The failure to find tubercle bacilli in a large number of similar cases can hardly be regarded as proof of their absence, when one considers the difficulty of demonstrating tubercle bacilli in small number irregularly distributed through a large mass without any lesion to indicate where they are most likely to be found. Gärtner finds that the transmission of tubercle bacilli from mother to fœtus is common in the experimental tuberculosis of mice, rabbits, and canary birds.

There is reason to believe that the embryo offers great resistance to the growth of tubercle bacilli. Maffucci has found that tubercle bacilli inoculated into hens' eggs before incubation remained quiescent during the period of embryonic development, but caused the death of most of the chicks from tuberculosis in three weeks to four and a half months after birth. We have evidence that in human beings living and virulent tubercle bacilli may remain latent in the body a long time. As already mentioned, the chances of penetration of bacilli into the fœtus appear to be more favorable during the later period of pregnancy than earlier. The frequency of tuberculosis increases very rapidly with each succeeding month after birth, until during the second half of the first year and during the second year of life fatal tuberculosis is very common, and then becomes less frequent until after puberty. Infantile tuberculosis is far more commonly situated in internal organs, such as the lymphatic glands,

meninges, bones, and joints, without tuberculous lesion on any exposed surface of the body, than is tuberculosis of adults.

These are the arguments which are urged by Baumgarten and others with great force in favor of frequent bacillar heritage. The majority of authorities, however, are reluctant to abandon the older views, and the final settlement of this important question involves great difficulties not likely to be soon overcome.

The portal of entry to the fœtus is the umbilical vein, and therefore micro-organisms would be carried first to the liver and the right side of the heart. Corresponding to this, we find that lesions of the liver and of the right side of the heart are particularly common in congenital infections. Pyogenic cocci, as already mentioned, break through the placental barrier with comparative ease, and these are the bacteria most often associated with endocarditis, which is more common on the right side of the heart in the fœtus and new-born than in the adult.

Although the fœtus may react to pathogenic micro-organisms in the same way as the mother, or even more severely, it possesses a remarkable insusceptibility to some infections, as has been proven experimentally and clinically. There are several instances in which the specific bacteria of croupous pneumonia and of typhoid fever have been found in the stillborn embryos of mothers affected with these diseases, but there is no satisfactory recorded instance of an infant born with the lesions of typhoid fever or those of lobar pneumonia caused by the pneumococcus. Some bacteria which cause localized infections in the mother may produce in the fœtus general septicæmia without localizations.

General Considerations concerning Pyogenic Bacteria.

The pyogenic bacteria play such a predominant rôle in surgical infections, and their pathogenic characters present so many peculiarities, that it is appropriate to consider here the general relations of pyogenic bacteria to surgical infections, although the consideration of the special diseases caused by these bacteria does not fall within the scope of this article.

There are no specific bacteria of suppuration. On the one hand the number of bacteria which under special conditions are capable of causing suppurative inflammation is large, and is not limited to any particular group, and on the other hand the bacteria which are most frequently the cause of suppuration are capable of causing other forms of inflammation and of producing infection without inflammation.

Certain staphylococci and streptococci, however, are found in purulent inflammations in human beings so much more frequently than other micro-organisms that they are the pyogenic bacteria *par excellence*, and are the ones generally understood when the expression "micro-organisms of pus" or "pyogenic bacteria" is used without any qualification. These staphylococci and streptococci are endowed with pus-producing properties in larger measure than are other bacteria, and of all their pathogenic effects the production of suppurative inflammation is the most prominent.

The most common pyogenic cocci are the staphylococcus pyogenes aureus, the streptococcus pyogenes, and the staphylococcus pyogenes

albus, including the staphylococcus epidermidis albus. In the second rank, as regards both frequency and virulence, are the staphylococcus pyogenes citreus, the staphylococcus cereus albus, and the staphylococcus cereus flavus. More common and far more important than the cocci of the latter group are the micrococcus lanceolatus and the micrococcus gonorrhœæ. Although these are not always ranked among the pyogenic cocci in the restricted sense, they are genuine pus-producers. The micrococcus tetragenus septicus is rarely the sole cause of suppuration. The status of the micrococcus pyogenes tenuis is uncertain. It is perhaps identical with the micrococcus lanceolatus.

There is a long list of bacilli which have been shown with greater or less certainty to be capable of producing suppurative inflammations in man. The principal ones are bacillus pyogenes fœtidus, bacillus coli communis, bacillus typhi abdominalis, bacillus tuberculosis, bacillus pyocyaneus, bacillus pneumoniæ of Friedländer, bacillus proteus. Actinomyces belongs to the class of schizomycetes and is a pus-producer.

Several anaërobic bacilli have been found both in pure culture and associated with other bacteria in closed abscesses. Of these may be especially mentioned bacillus phlegmones emphysematosæ of E. Fraenkel, which is probably identical with bacillus aërogenes capsulatus previously described by Welch and Nuttall, and which occurs in some phlegmons containing gas.

The list of demonstrated pus-producing bacteria is by no means exhausted by those enumerated. In the experience of the writer bacilli are more common causes of spontaneous abscesses in laboratory animals than cocci. A very large number of bacteria are capable of producing experimental abscesses in animals.

It is fair to say that not all of the bacteria mentioned above are recognized as pyogenic for man by all authorities, and particularly that some do not so regard the typhoid bacillus and the tubercle bacillus; but in the opinion of the writer their pyogenic capacity has been demonstrated.

We have very little definite information as to the underlying conditions which control the pyogenic manifestations of such bacteria as the typhoid bacillus, the tubercle bacillus, and others which do not ordinarily cause purulent inflammations. These conditions seem to pertain partly to the degree of virulence of the micro-organism and partly to the local susceptibility of the tissues invaded and the general susceptibility of the individual. We find in experiments upon animals that bacteria of weakened virulence in susceptible animals, or those of usual virulence in insusceptible animals, are prone to produce localized abscesses. In an animal which has been rendered artificially immune from septicæmia caused by certain pathogenic bacteria immunity is not usually produced from the development of local abscesses by the specific organism, in case this is capable of forming abscesses.

Statistical statements as to the relative frequency with which the different pyogenic cocci occur in general in suppurative and septic affections vary according to the class of cases which preponderate. The staphylococcus aureus is by far the most common micro-organism in furuncles and osteomyelitis, and is common in circumscribed subcutaneous abscesses. The streptococcus pyogenes is by far the most common organism in

spreading plegmonous cellulitis, inflammations of serous membranes, puerperal infections, and septicæmia. It is the cause of erysipelas in practically all cases of this disease. It is a frequent cause of all kinds of inflammations of the throat and of broncho-pneumonia. The staphylococcus albus is often associated with the other pyogenic cocci, especially in inflammations involving the skin. It occurs most frequently in the same general class of cases as the staphylococcus aureus. Although capable of causing grave infections, the characters of the inflammations in which the white staphylococcus is found alone are usually mild. Two or more species of pyogenic cocci are often combined.

The relative frequency of occurrence of the pyogenic cocci seems to vary somewhat according to the locality. Levy finds in Strassburg the staphylococcus albus more frequently than the staphylococcus aureus in all suppurative affections except furuncles, and he was unable to confirm the usual statement that the albus is less virulent than the aureus.

The following table gives the results of the bacteriological examination of 135 ambulatory and operative surgical cases by Dowd[1] in the Vanderbilt Clinic and Cancer Hospital in New York. It affords a good idea of the relative frequency of the different pyogenic cocci in the class of cases which most frequently come to the attention of the surgeon:

	Cellulitis, 51 cases.	Infected fresh wounds, 17 cases.	Old granulating wounds, 18 cases.	Healing wounds, stitches, 5 cases.	Furuncles, 7 cases.	Abscesses, 37 cases.
Streptococcus pyogenes alone	9	3	. .	. .	. .	8
Streptococcus pyogenes predominant	23	3	. .	. .	. .	8
Streptococcus pyogenes relatively few	3	1	6	. .	. .	1
Staphylococcus pyogenes aureus alone	11	1	1	1	7	6
Staphylococcus pyogenes aureus predominant	8	2	. .	. .	. .	1
Staphylococcus pyogenes aureus relatively few	13	3	. .	. .	. .	2
Staphylococcus pyogenes or epidermidis albus alone	1	4	2	4	. .	2
Staphylococcus pyogenes or epidermidis albus predominant	. .	1				
Staphylococcus pyogenes or epidermidis albus relatively few	10	5	3	. .	. .	6
Staphylococcus cereus albus	3	1	2	. .	. .	1
Staphylococcus citreus	1	. .	2	. .	. .	1
Bacillus pyocyaneus	. .	. .	1	. .	. .	3
Bacillus coli communis	. .	. .	. .	. .	. .	3
Very few growths on agar	. .	. .	3	. .	. .	3
No growths on agar	. .	. .	. .	. .	. .	11
Few undetermined colonies	12	2	5	. .	. .	5

The cases from which no growth occurred were tuberculous abscesses and buboes. 8 of the 51 cases of cellulitis showed a persistent tendency to spreading inflammation with undermining of the tissues. In all of these 8 cases streptococci were found. In 2 cases of pyæmia staphylococcus aureus and streptococci were present in the original wound, but only streptococci in the metastases.

It is interesting to contrast with these results of the examination

[1] Charles N. Dowd, "Some Considerations on Different Types of Exudative Inflammation," *Medical Record*, New York, Sept. 8, 1894.

of ambulatory and operative surgical cases the results of the bacteriological examination of post-mortem cases. In about 500 autopsies at the Johns Hopkins Hospital there were found in 185 cases the following bacteria:

	Number of cases.
Bacillus coli communis	105
Streptococcus pyogenes	62
Staphylococcus pyogenes aureus	43
Micrococcus lanceolatus	29
Staphylococcus pyogenes albus	14
Bacillus typhosus, as the cause of special complications	7
Bacillus pyocyaneus	8
Proteus	4
Micrococcus tetragenus	2
Staphylococcus pyogenes citreus	1
Pneumobacillus of Friedländer	1
Bacillus pyogenes fœtidus	3
Bacillus aërogenes capsulatus	3
Undetermined bacteria	35

The streptococcus cases do not include those in which streptococci were found only in phthisical cavities or adjacent lung. The cases with micrococcus lanceolatus are those in which this organism was found without pneumonia or as the cause of some extra-thoracic complication of pneumonia. No cases are included in which the bacteria were found simply on exposed surfaces of the body. Among the undetermined bacteria are several interesting pathogenic forms which could not be positively identified with species already described. Mention has already been made of the frequent invasion of the colon bacillus without any pathogenic manifestations.

The preceding table is inserted not with the intention of analyzing in this article the cases[1] composing it, but to show the great differences between the results of the bacteriological study of living surgical cases and those of the autopsy material of a general hospital, and especially to emphasize the preponderance of streptococcus cases over staphylococcus and all other pyogenic cases in such material.

All of the affections caused by one species of the pyogenic cocci may be caused by any of the others. For example, the staphylococcus aureus may produce spreading phlegmons, inflammations of serous membranes, puerperal infections, general septicæmia as well as the streptococcus pyogenes, and the streptococcus pyogenes may cause circumscribed abscesses and osteomyelitis as well as the yellow or white staphylococcus. Jordan claims that the staphylococcus aureus may cause erysipelas, but Petruschky does not regard his observations on this point as conclusive.

Furthermore, these pyogenic staphylococci and streptococci may cause all kinds of inflammation besides the suppurative. They may, and often do, cause serous, sero-fibrinous, and fibrinous inflammations of serous membranes. The streptococcus pyogenes may cause catarrhal and fibrinous inflammations of mucous membranes. Pyogenic cocci may be the cause of simple inflammatory œdema or serous infiltration of the tissues. They are sometimes found in cutaneous vesicles and blebs containing clear serum. They may be the sole organisms present when

[1] The analysis of these cases was the subject of the Middleton Goldsmith lecture by the writer in April, 1894 (*Trans. N. Y. Pathological Society* for 1894).

the inflammatory exudate is hemorrhagic. They may produce extensive necrosis of the tissues with scarcely any inflammatory exudate. We find the same staphylococci and streptococci in those rarer forms of osteomyelitis which do not suppurate as in the ordinary suppurative form. They are the usual cause of periostitis and ostitis albuminosa, in which the exudate is serous. A serous or sero-fibrinous inflammation caused by pyogenic cocci may be transformed into a purulent one without the appearance of any new species of micro-organism.

We cannot at present give any satisfactory explanation of these diverse effects produced by one and the same bacterial species. We seek to explain these differences usually by referring to such factors as the degree of virulence of the organism, the manner of its invasion, the site of infection, and the condition of the patient. Variations in virulence and the general condition of the patient cannot be the sole explanation, for these pyogenic cocci may in the same individual cause a suppurative inflammation in one part of the body and a serous or a sero-fibrinous inflammation in another part, without any bacteriological difference. We have observed this in some instances of multiple serositis, and Schrank has reported a case in which periostitis albuminosa was associated with suppurative osteomyelitis in the same tibia. The same micro-organisms, staphylococci and streptococci, were present in the exudate in both situations. They had produced pus in the bone-marrow and a simple serous exudate between the periosteum and bone. The deciding factor must have been in the tissues, and not in the micro-organisms or the general predisposition of the individual, and this same factor, the specific character of the tissues, little as we may comprehend its nature, is doubtless the explanation of their varying reactions to the same infectious agents in many other cases—a point which has been justly emphasized by Kurt Müller.

It might be inferred from what has been said as to the interchangeable effects produced by the different pyogenic cocci that no diagnostic or prognostic importance is to be attached to the determination of the particular species of pyogenic coccus present. If the streptococcus can do everything which the staphylococci can do, if each species can produce mild as well as grave infections, it is argued by some that it is of no practical importance to determine what particular micro-organism is present in a given case.

It is more important for the surgeon to understand the general relations of bacteria to traumatic and other pyogenic infections than to become familiar with the special characters of the individual micro-organisms which cause these infections, and therefore the principal part of this article has been devoted to a consideration of these general relations. But apart from the interest which pertains to the study of all aspects of disease, even those without evident practical bearings, it would be a mistake to suppose that the bacteriological examination of infectious processes caused by pyogenic cocci is devoid of value for diagnosis, prognosis, or treatment.

There are certain general rules as to the characters of the infections most likely to be produced by the different species of pyogenic cocci, and as to the probability of finding a given species in a certain kind of infection. It would lead too far to attempt to consider here all the differ-

ent surgical infections with reference to these points. A few illustrative examples may be cited.

The white staphylococcus causes severe local and general infections so infrequently, at least in this country so far as we are informed, that the recognition of its exclusive presence in an inflamed external part of the body justifies the probable conclusion that the inflammation will pursue a mild course and be readily amenable to treatment.

The streptococcus pyogenes may possess all degrees of virulence. Although a streptococcus coming from a case of erysipelas or puerperal fever may not be distinguished botanically from a streptococcus coming from a healthy mucous membrane or caught from the air, it is a very different thing in its possibilities for infection. The streptococcus pyogenes, far more frequently than other bacteria, causes spreading phlegmonous inflammations and grave forms of septicæmia. The importance and the frequency of streptococcus septicæmias accompanying tuberculosis, diphtheria, typhoid fever, scarlet fever, the puerperal state, erysipelas, cellulitis, and traumatic infections are probably not even yet sufficiently appreciated by physicians and surgeons, notwithstanding the rapid extension of our knowledge of this subject in recent years. Septicæmias produced by other pyogenic cocci under these circumstances, although they may be of equal severity and similar character, are in a small minority.

In view of the fearful pathogenic possibilities with which streptococci may be endowed, a surgeon cannot regard the presence of these micro-organisms in a wound or inflamed part with as little concern as he may the white or even the yellow staphylococcus, although it may be that the particular streptococcus in question is of relatively slight virulence. If his patient have chronic Bright's disease or general arterio-sclerosis or chronic cardiac insufficiency, the anxiety of the surgeon will be increased. Inflammations of external parts produced by staphylococci are in general more amenable to treatment and require less vigorous interference than those caused by streptococci. Streptococcus cases are in general more dangerous to other surgical patients in their proximity than staphylococcus cases, and are therefore more likely to require isolation.

The gravest staphylococcus infection with which the surgeon has commonly to deal is acute osteomyelitis. In this particular field the staphylococcus aureus takes rank over the streptococcus, although there is no specific micro-organism of osteomyelitis any more than there is of suppuration in general. Osteomyelitis may be caused by the streptococcus pyogenes and other pyogenic bacteria, but, although these other bacteria not infrequently cause periostitis, they are very rarely the cause of uncomplicated suppurative osteomyelitis.

The especial conditions under which, in cases of infection caused by pyogenic cocci, the cocci appear in the blood in sufficient number to be demonstrable by our methods of examination are far from clear. We find them far more frequently in the blood at autopsies, even very fresh ones, than we are able to do during life. The pyogenic cocci, like most pathogenic bacteria, only exceptionally are able to multiply in the circulating blood of human beings. The greater frequency of their presence in demonstrable number at autopsy may be due in part to their multiplication after death, but this cannot be the sole explanation, as the cocci are found in autopsies made very early after death more frequently than

they are found during life. The explanation is probably that during the last hours of life they often find suitable conditions for their multiplication in the blood. A similar phenomenon can often be observed in inoculated animals. All bacteria, including those of the typical septicæmias of animals, such as the bacillus of rabbit septicæmia, of anthrax, the micrococcus lanceolatus, injected into the blood quickly disappear from the circulation. The pathogenic forms grow outside of the circulating blood, and often do not make their reappearance in any considerable number in the circulation until shortly before death and after the manifestation of grave constitutional symptoms. This is true of pneumococcus septicæmia, anthrax, and other typical septicæmias of animals.

In examining the blood of living patients for pyogenic cocci a few drops of blood do not generally suffice, as the cocci are rarely so numerous as to be detected thus. The blood is obtained by wet cups by Petruschky, who has developed a special technique for these examinations. To the demonstrations of the white staphylococcus in blood withdrawn by cutting or pricking the skin, which have been made by a number of investigators, the writer attaches no diagnostic significance, for reasons which have been stated. The detection of streptococci is significant. Petruschky and Canon found streptococci in the blood during life in a number of cases of pyæmia, septicæmia, and localized infection. They were more likely to be present in severe than in the milder cases, but they were occasionally found in cases which recovered, and even in very mild infections. Cocci are found in the blood in cases both with and without metastases.

Doubtless pyogenic cocci often enter the circulation in small number from a localized focus of inflammation caused by them. They are often disposed of without doing any harm by the bactericidal cells and fluids. Their fate, however, is not always one which is so advantageous to the patient. They may lodge and grow in internal parts, causing inflammations of serous membranes, ulcerative endocarditis, and other metastatic inflammations. They may survive, and even multiply, in the blood, with or without the production of metastases. These general infections, particularly those with the streptococcus pyogenes, are far more likely to occur with primary localized infections, such as erysipelas, infected wounds, abscesses, in persons with chronic Bright's disease, and other conditions which we have repeatedly specified as predisposing causes, than in previously healthy persons.

The usage has grown up among bacteriologists of limiting the name "septicæmia" to infections characterized by a large multiplication of bacteria in the blood during life. Septicæmias in this bacteriological sense occur in man, but they are not common. Far more common are cases of human septicæmia in which a moderate or small number of pyogenic cocci are found in the blood, but there is no definite relation between the number of bacteria in the blood and the character and gravity of the symptoms. We cannot explain these symptoms nor some of the lesions without assuming that they are referable to the action of toxic products of the bacteria, and that these toxic products may be absorbed from localized foci of inflammation.

There are no specific bacteria of either septicæmia or pyæmia. The same bacteria are found in both diseases.

Bacteria of Surgical Infections.

The leading characters, especially the pathogenic, of the bacteria concerned in surgical infections will here be briefly described. Certain rare and unnamed and insufficiently identified bacteria which have been described as occurring in surgical diseases will not be considered.

Staphylococcus Pyogenes Aureus (Plate II., Fig. 5).—Observed by Ogston (1881), first accurately described by Becker (1883), Rosenbach (1884), and Passet (1885). Appears in the form of spherical cells, averaging 0.8 μ in diameter, which by differential staining often show a diplococcus or biscuit shape. Occurs usually in clumps, also in pairs and short chains. May be found both within and outside of pus-cells in abscesses. Stains readily with aniline dyes, including Gram's stain. Forms an orange-yellow pigment, but only in the presence of free oxygen. Grows at ordinary temperatures, most rapidly at body temperature. Grows on all culture media both with and without free oxygen. Liquefies gelatin rapidly. Coagulates milk; clouds bouillon. May survive in dried pus for one hundred days; is killed in a much shorter time by desiccation when contained in thin media. In the moist condition is killed in ten minutes by a temperature of 58° C. (Sternberg). When dried a higher temperature—90–100° C.—is required to kill it in a short time. In bouillon cultures all of the cocci may be killed in five minutes by sublimate, 1 : 1000, but frequently some survive longer, even up to thirty minutes (Abbott). Killed in a few seconds by 3 per cent. carbolic-acid solution. Virulence variable. Pathogenic properties for animals and man have already been described. (See pp. 280, 289, 303, and the preceding section, "General Considerations concerning Pyogenic Bacteria.")

Staphylococcus Pyogenes Albus.—Cultivated by Rosenbach from pus in 1884. Differs from the aureus only by absence of pigment. As the pigment may form in aureus cultures very slowly, the cultures should be watched for several days, up to two weeks, before making a diagnosis of the albus. Pathogenic effects similar to those of the aureus, but usually the virulence of the albus is less than that of the aureus.

Staphylococcus Epidermidis Albus (Welch).—Is probably only a variety of the staphylococcus pyogenes albus. Usually grows somewhat more slowly; liquefies gelatin and coagulates milk less rapidly. Is of little virulence under ordinary conditions. Is a regular inhabitant of the epidermis, lying deeper than can be reached by disinfection of the surface of the skin. Its behavior has already been described (pp. 251, 270, and 272).

Staphylococcus Pyogenes Citreus.—Cultivated by Passet from abscesses (1885). Differs from the aureus and albus only by forming lemon-yellow pigment in the presence of free oxygen. Pathogenic effects similar to those of the aureus and albus; often of less virulence than the aureus, but may be highly virulent. Is found less frequently than the preceding staphylococci.

Staphylococci forming pigments intermediate in tint between the aureus and citreus occur, also cocci with the production of only a very faint yellowish color, perhaps produced only after prolonged growth. This has led Lubinski and others to the view that these various pyogenic staphylococci are only physiological varieties of one and the same species.

Staphylococcus Cereus Albus.—Cultivated from two abscesses by Passet (1885). Pyogenic power not considered to be demonstrated by Passet and Flügge. Levy, however, found this coccus in pure culture in abscesses and other inflammations, and produced suppuration by inoculating it into the rabbit's eye. Resembles the aureus and albus, but it does not liquefy gelatin and it forms no pigment.

The *staphylococcus cereus flavus* was isolated by Passet in pure culture from a chronic suppurative periostitis, but it does not appear to have been found again in abscesses. Passet was unable to cause abscess by inoculating it into animals. Differs from the staphylococcus cereus albus only by the formation of lemon-yellow pigment.

Streptococcus Pyogenes; Streptococcus Erysipelatos (Plate I., Fig. 3).—Observed by Ogston in pus (1881); cultivated by Fehleisen from erysipelas (1883), by Rosenbach from pus (1884). The streptococcus of erysipelas does not differ in morphology or cultural characters from the streptococcus pyogenes. The same pathogenic effects may be produced by each in animals and in man, so that the weight of evidence is in favor of the identity of the streptococcus erysipelatos with the streptococcus pyogenes, although opinions are still divided on this question.

The streptococcus pyogenes grows in chains of variable length. The individual cocci vary in size, sometimes in the same chain. They average somewhat larger than the staphylococci. In pus they occur in chains, also in pairs. Stain readily with aniline dyes and by Gram's method. Grow with or without free oxygen in all ordinary culture media. Most streptococci grow at room temperature, but more slowly than at body temperature. The streptococcus pyogenes does not liquefy gelatin, or does so slightly in some cases. Forms small, gray, granular colonies on gelatin and agar. Grows invisibly on potato, but may grow visibly. May or may not coagulate milk and cloud bouillon. Some cultures are short-lived, others may live several months. The streptococcus pyogenes may survive in dried pus for fourteen to thirty-six days. Is killed in ten minutes by exposure to 54° C. (Sternberg). Is killed in eight seconds by 3 per cent. carbolic-acid solution. Inoculated cutaneously into the rabbit's ear, virulent streptococci usually produce erysipelas, from which the animal recovers. The virulence is extremely variable, and is best tested by inoculating mice into the peritoneum, either with the first generation of a pure culture or directly with the blood or exudates containing the streptococci. Very virulent streptococci in small doses produce rapidly fatal septicæmia in mice; less virulent ones, a more or less protracted septicæmia or local inflammations; and the mouse may die after a longer or shorter period from the effects of the inoculation without the presence of streptococci at the autopsy. Streptococci are often devoid of virulence for mice. The virulence for mice does not correspond definitely to the character and severity of the streptococcus infection in the patient from whom the streptococci were obtained, although it is a general rule, with many exceptions, that the most virulent streptococci come from grave streptococcus infections in man. The pathogenic properties of streptococci for man have already been mentioned so far as they relate to surgical infections. (See pp. 258, 259, 292, and the preceding section, "General Considerations concerning Pyogenic Bacteria.")

Streptococci obtained from different sources, and even those cultivated from different cases of the same disease, vary greatly in morphology, cultural characters, and pathogenic properties. So far as virulence is concerned, this property alone cannot serve as a basis of distinction into species, as this is the most variable of all properties of pathogenic micro-organisms, and in the case of no micro-organism more variable than with the streptococcus pyogenes. The virulence of streptococci appears to vary not only in degree, but in kind, so that a streptococcus endowed with the property of producing one kind of infection—as, for example, erysipelas—may not be qualified under ordinary conditions to produce another kind of infection—as, for example, an abscess. But we observe such ready transformations in these varying degrees and qualities of virulence, and such modifications of the pathogenic effects by other circumstances than the virulence, such as the manner and site of invasion and the susceptibility of the individual, that it seems hopeless to attempt any division into physiological varieties on the basis of the quantity and quality of virulence, significant as this property is for our understanding of diverse streptococcus diseases in man.

Many attempts have been made to establish different species or varieties of streptococci on the basis of morphological, cultural, and pathogenic differences. These attempts have met with only partial success. They have tended to demonstrate the great variability of one and the same species, rather than to establish definite and constant distinctions between supposedly different species or varieties. So far, at least, as the streptococci which we ordinarily meet, and particularly those of interest for human pathology, are concerned, most authorities are of the opinion that no satisfactory division into separate species can at present be established, although it is convenient to classify streptococci according to certain prominent but varying characteristics. The characteristics which are most useful in this classification are those which appear in bouillon cultures. They are the length of the chains, the presence or absence of cloudiness of the bouillon, and the kind of sediment produced by the growth of the cocci. We thus distinguish short-chained streptococci (*streptococcus brevis*), long-chained streptococci (*streptococcus longus*), streptococci which render bouillon cloudy and those which do not, streptococci which form flocculent or sandy or scaly or viscous sediments. The name *streptococcus conglomeratus* is given to a streptococcus which grows, without clouding the bouillon, in the form of dense, separate particles, scales, or thin membranes at the bottom and sides of the tube, and on shaking the sediment it breaks up into little specks without producing uniform, diffuse cloudiness. On microscopical examination the chains in the latter case are long and interwoven in conglomerate masses. Streptococcus chains may be straight or wavy or twisted. These various distinctions are only of relative value. One form may change into another. Virulent streptococci may be found among all the groups mentioned. The streptococcus of erysipelas and most of the streptococci from abscesses and septicæmia grow in long chains in bouillon.

Micrococcus Tetragenus.—Isolated by Koch and Gaffky (1881) from phthisical cavities. Grows in tetrads enclosed in gelatinous capsules. Stains by Gram. Grows on all media at room temperature, with or

without oxygen. Forms elevated, white, non-liquefying colonies on gelatin. Pathogenic for mice, guinea-pigs, and, by intravenous and intra-peritoneal inoculation, also for rabbits. Found not infrequently in phthisical cavities and sputum, occasionally in association with pyogenic cocci in abscesses connected with carious teeth and about the neck and jaws and middle ear, rarely in abscesses elsewhere. It has been considered to be non-pathogenic for man, but it has been found in pure culture in closed abscesses in man, and Viquerat has proven experimentally that it is capable of causing suppuration in human beings. He considers that suppurations produced by the tetragenus alone are mild in character, painless, with little reaction, easily cured. Boutron proposes the name "micrococcus tetragenus septicus" for the Koch-Gaffky micrococcus to distinguish it from other similar tetragenous cocci. The latter are non-pathogenic.

Micrococcus Lanceolatus (Plate I., Fig. 5).—Synonyms: Diplococcus pneumoniæ, Pneumococcus of Fraenkel and Weichselbaum, Diplococcus lanceolatus, Micrococcus of sputum septicæmia, Micrococcus pneumoniæ cruposæ, etc. Discovered by Sternberg in his saliva in 1880. Demonstrated to be the cause of lobar pneumonia by Fraenkel and by Weichselbaum in 1886. Capsulated, lance-shaped coccus, occurring usually in pairs and short chains, sometimes in long chains. Stains by Gram. Grows best at body temperature; may grow at temperature of 18–22° C. Capable of cultivation on all ordinary alkaline media, but susceptible to slight variations in composition of culture medium. Colonies small, round, gray. Does not liquefy gelatin. Faculative anaërobe. Loses virulence and dies quickly in cultures. May survive in dried sputum or blood for four months. Killed in ten minutes at 52° C. Virulence and other properties extremely variable. Pathogenic for mice and rabbits, in less degree for guinea-pigs. Causes localized inflammations and septicæmia.

Present often in the mouth of healthy human beings (page 258). Next to the pyogenic staphylococci and streptococci, it is the most common cause of inflammations in human beings. It is probably the sole specific cause of genuine acute lobar pneumonia, and a frequent cause of broncho-pneumonia, otitis media, and meningitis. With or without pneumonia it may cause inflammation in any organ or part of the body. It can produce all kinds of inflammatory exudates—serous, sero-fibrinous, purulent. It most frequently invades the body from the bronchi or lungs, sometimes from the nose, nasal sinuses, and pharynx, and occasionally from the intestine. The list of diseases which it is capable of producing is a very long one, including inflammations of any of the mucous and serous membranes, abscesses in any part of the body, mono- and poly-arthritis, osteomyelitis, periostitis, parotitis, thyreoiditis, nephritis, acute ulcerative endocarditis, etc. It may cause septicæmia with single or multiple localizations. It is the most frequent cause of metapneumonic pleurisies, including empyæma. Although it may cause the gravest diseases, it is ranked as a relatively benign organism in comparison with the streptococcus pyogenes, particularly in pleurisies and suppurations. It may die quickly in inflammatory exudates, as well as in cultures, but it may also persist weeks and months.

Micrococcus Pyogenes Tenuis.—Found by Rosenbach in pus (1884).

Has been described in about twelve cases of suppurative inflammation. It is probably identical with the micrococcus lanceolatus (Neumann).

Micrococcus Gonorrhœæ or *Gonococcus* (Plate I., Fig. 4).—Discovered by Neisser in gonorrhœal pus in 1879. First cultivated by Bumm in 1885 on human blood-serum. Found constantly in gonorrhœal pus. The cocci are in pairs, with the adjacent sides flattened against each other, with a clear interspace (biscuit shape). Groups of four with adjacent sides flattened also occur. Particularly characteristic is the inclusion of the cocci within leucocytes, but they occur also free and attached to epithelial cells. Of diagnostic importance is failure to stain by Gram, which distinguishes the gonococcus from all the preceding cocci, but not from the so-called pseudo-gonococci (pp. 266 and 267). Facultative anaërobe. Grows only at body temperature or neighboring temperature. Does not grow on nutrient gelatin or plain agar, or on the latter only with difficulty and occasionally. Grows best on a mixture of human blood-serum and nutrient agar (one to two or three parts) (Wertheim). The addition of sterile human urine improves the serum-agar mixture (Steinschneider). Surface colonies pale, grayish, translucent, finely granular, with finely notched borders. Forms a membrane in bouillon and blood-serum mixed, leaving the fluid clear. Cultures on serum-agar when prevented from drying may live forty-five days. Inoculation of pure cultures into healthy human urethræ produces typical gonorrhœa. The gonococcus is a strict human parasite. It dies quickly in dried pus outside of the body. Virulence soon disappears, as a rule, in artificial cultures.

The gonococcus is in general non-pathogenic for animals, but when inoculated with bits of agar into the eye or into the peritoneal cavity of mice and guinea-pigs it may cause suppurative inflammation. In human beings its growth is usually superficial, and by preference on mucous membranes covered by cylindrical or transitional epithelium, but it may grow down deeply into connective tissue and between muscle-fibres, and may attack mucous membranes covered by flat epithelium. It is the cause of most cases of salpingitis, pyosalpinx, and the accompanying peritonitis. It may produce genuine abscesses (ovarian, peri-urethral). It may be conveyed by the blood-current and cause inflammations in distant parts, most commonly arthritis, also endocarditis, pericarditis, pleurisy, and myocarditis. Every condition of rigid proof of the causation of arthritis by the gonococcus (exclusive presence, isolation in pure culture, and experimental production of gonorrhœa by inoculation) has been fulfilled. It is the usual cause of gonorrhœal rheumatism. All these conditions, complicating gonorrhœa, may, however, be produced by other invading micro-organisms or be mixed infections with the gonococcus.

Bacillus Pneumoniæ of Friedländer (Pneumo-bacillus or Pneumonia of Friedländer).—Isolated by Friedländer in 1883 from croupous pneumonia. Short, plump rods with rounded ends provided with discapsules in the animal body. Does not stain by Gram. Facultative probe. Grows at room temperature. Forms prominent, opaque-white, liquefying colonies on gelatin. Grows on all media. Ferments glucid lactose and produces gas-bubbles on potato. Pathogenic for less so for guinea-pigs, and still less so for rabbits, which, however, some infected by intra-peritoneal inoculation. Found occasionally

in the healthy human mouth and nose, also outside of the body. It is found most frequently in inflammations of the mouth, nose, and middle ear. It may cause broncho-pneumonia, and has been observed in a very few cases of empyæma and of meningitis secondary to middle-ear disease and to injury. It is a rare organism in this country.

The *bacillus of rhinoscleroma* resembles closely the Friedländer bacillus, and, according to some, there is no reliable differential character, not even the greater resistance to decolorization by Gram's method, which has been the point chiefly emphasized. There is a group of capsulated bacilli, resembling the Friedländer bacillus, some from human beings, others from animals, which have not been satisfactorily differentiated from each other (see page 262).

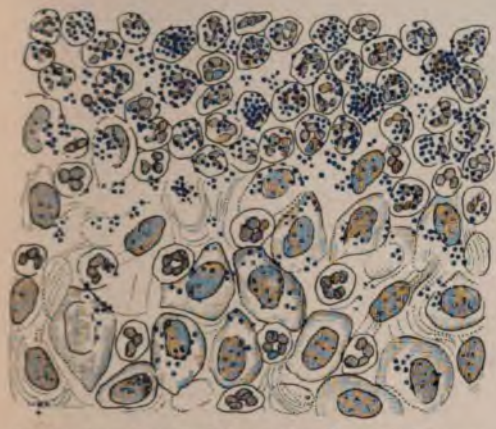
Bacillus Pyocyaneus (Plate I., Fig. 2).—First cultivated by Gessard from blue pus (1882). A slender, motile, liquefying bacillus, decolorized by Gram, growing rapidly, even at ordinary temperatures, in all culture media. In the presence of oxygen forms bluish, fluorescent green and a whole scale of pigments. Interesting modifications of character, especially as to color production, can be produced artificially, and are observed under natural conditions, constituting, according to some writers, distinct varieties of the bacillus. Is widely distributed, occurring often on the human skin, in the fæces, and outside of the body. In wounds stains the dressings bluish green, and produces a somewhat characteristic offensive odor. Increases suppuration of wounds, usually with little constitutional disturbance. Pathogenic for animals. Is found not infrequently in perforative peritonitis and appendicitis, sometimes in phlegmons, otitis media, broncho-pneumonia, and inflammations of serous membranes, associated usually with other bacteria. It was found by Ernst in tuberculous pericarditis (Plate I., Fig. 2). Often found in diarrhœal and dysenteric discharges. May cause general infections in human beings. With or without general infection it may cause hemorrhagic and necrotic enteritis, a form of pyocyaneus infection in human beings which we have repeatedly observed at autopsy. Instances of invasion of the body from wounds by the bacillus pyocyaneus have not been observed.

Bacillus Pyogenes Fœtidus.—First cultivated by Passet from stinking pus of a perirectal abscess (1885). Short bacilli with rounded ends. Cultures have a foul odor; in other respects they do not appear to differ from those of the bacillus coli communis. This bacillus probably belongs to the group of colon bacilli. It has been found in pure culture in closed abscesses, but more frequently is associated with other bacteria.

Bacillus Coli Communis.—Isolated by Escherich from fæces of infants (1886). There is a group of bacilli, called the colon group, presenting similar characters, but with much variation in their cultural and other properties. Short rods with rounded ends, also longer forms. Either motile or non-motile. Do not stain by Gram in cultures or in the tissues, but do in normal stools. Grow at low as well as high temperatures on all media. Facultative anaërobes. Form large, spreading, grayish-white, non-liquefying colonies with notched borders on gelatin and agar, sometimes circumscribed, round, white colonies. On potato, brownish, yellowish, white, or even scarcely visible growth. Coagulate milk, ferment glucose, lactose, and maltose. Constant inhabitants of the intestine, also widely

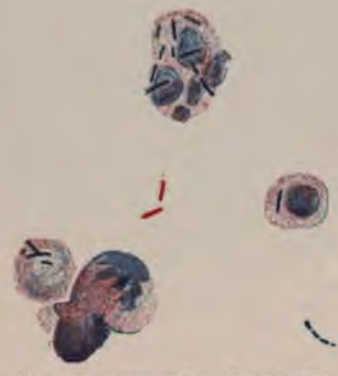
PLATE I.

FIG. 1.



Section through wall of abscess showing staphylococcus pyogenes aureus (p. 315). BAUMGARTEN.

FIG. 2.

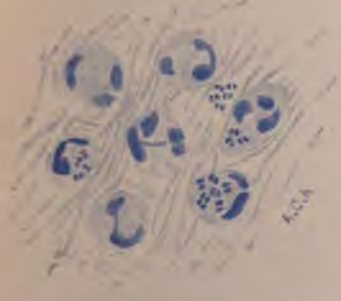


Cover-glass preparation of pericardial exudate showing bacillus pyocyaneus stained blue, and the tubercle bacillus stained red (p. 320). ERNST.

FIG. 3.

Streptococcus pyogenes; streptococcus erysipelatos (p. 316). PRUDDEN.

FIG. 4.



Micrococcus gonorrhœæ or gonococcus *(p. 319).* *ABBOTT.*

FIG. 5.

Micrococcus Lanceolatus (p. 318). ABBOTT.

distributed in external nature. The colon bacillus is a frequent invader of the internal organs in all sorts of diseases, especially when there are intestinal lesions. It manifests no evident pathogenic action in most of these cases, and is then without clinical significance. It occurs frequently associated with other bacteria in infected wounds and other inflammations of exposed surfaces. Here also it does not usually appear to cause serious disturbance. The fact that the colon bacillus is so common and widely distributed, and found so often as a harmless invader, should lead to much caution in interpreting the significance of its presence when it occurs in definite lesions. There is no doubt, however, that it may be pathogenic for man. It plays an important rôle in inflammations of the urinary tract and biliary passages; also, but usually with less independence, in peritonitis and appendicitis. The list of diseases in which it may be found is a very long one, and includes inflammations in all organs and parts of the body. Attention has already been called to its pathogenic properties for man (page 274). In general these properties are of a mild character. One of its leading rôles is to invade territory already occupied by other bacteria or previously damaged. It may be concerned in the production of gall-stones, in the interior of which it has been found by the writer with great frequency. Its virulence as tested upon animals is variable, but is generally manifest only after inoculation of large doses, which kill by intoxication rather than infection.

Bacillus lactis aërogenes is described by Escherich as shorter and plumper than the colon bacillus. Forms more circumscribed, elevated, white colonies, and coagulates milk and produces gas on potato more quickly and energetically than the latter. Predominates in the upper part of the small intestine. Of late most writers include this bacillus in the colon group, with which it corresponds in its general pathogenic characters. It is sometimes described as an opaque variety of the colon bacillus.

Bacillus Typhi Abdominalis.—Mention is made of this bacillus, which is chiefly of medical interest, not to describe its characters, but to call attention to its capacity in rare instances to produce genuine suppurative inflammations in man, and especially to cause periostitis and osteomyelitis as a sequel of typhoid fever. Most suppurations accompanying or following typhoid fever are due to the pyogenic cocci or are mixed infections, but the typhoid bacillus may occur alone in abscesses. The most common post-typhoid osseous affection is periostitis with cortical ostitis. The exudate, when caused by the typhoid bacillus alone, may be dark and thin with much detritus, or syrupy in consistence, or genuine pus. The affection is oftener in the ribs than elsewhere, and may be obstinate toward treatment. It may develop several months, and it has been claimed even years, after typhoid fever. Some observations indicate that the typhoid bacillus may cause meningitis and inflammations of serous membranes.

Bacillus Proteus.—In 1885, Hauser isolated from putrefying substances the rapidly-liquefying *proteus vulgaris*, the slowly-liquefying *proteus mirabilis*, and the non-liquefying *proteus Zenkeri*, which he originally supposed to be three distinct species, but which he now regards on satisfactory evidence as three varieties of the same species, called bacillus proteus. The main characters of this bacillus are its

pleomorphism, and especially moving, wandering, irregular projections and islands from its colonies on gelatin and agar (swarming colonies). It is motile. This is one of the most widely-distributed bacteria, and is concerned in the decomposition of animal and vegetable material. It is not uncommon in the intestinal contents. Although repeatedly observed in inflammations of exposed surfaces, in appendicitis, in perforative peritonitis, and even in closed abscesses in association with other bacteria, it has been generally considered to be non-pathogenic for man, but our autopsy material has convinced us that it may be pathogenic. It may be unassociated with other bacteria in abscesses and in peritonitis, and it may cause general infection by invading the blood and internal organs (Flexner). In moderate and large doses it is pathogenic for animals.

Bacillus Œdematis Maligni.—Long spore-forming bacillus resembling the anthrax bacillus, but narrower and with rounded ends. Forms long threads. Strict anaërobe. Liquefies gelatin with gas-production and foul odor. Widely distributed in the soil and in the fæces of animals. Pathogenic for animals. No instance is recorded of infection of a previously healthy person with this bacillus, but Brieger and Ehrlich have reported two cases of malignant œdema following the hypodermic injection of musk in a typhoid patient. The bacilli were accidentally introduced by the syringe.

Bacillus Aërogenes Capsulatus; Bacillus Phlegmones Emphysematosæ.—An anaërobic bacillus first described by Welch and Nuttall in 1892 as the cause of rapid formation of gas in the blood-vessels and organs after death. Capsulated thick bacillus, averaging 3 to 6 μ in length. Readily stained by aniline dyes, including Gram's stain. Grows slowly at room temperature, best at body temperature. Produces gas abundantly in all media containing fermentable substances. Does not form spores. When injected subcutaneously or intravenously into animals which are killed shortly afterward, it develops rapidly, with abundant formation of gas throughout the body. The gas is odorless and burns with a blue flame. There is at first no putrefactive decomposition. In the first case reported by Welch and Nuttall the autopsy was made eight hours after death in cool weather, and gas was abundant in the blood-vessels and liver. This bacillus is doubtless the cause of the gas-formation in many cases reported as death from the entrance of air into the veins, especially from the uterus after abortion, as was proven to be true in a case reported by Graham, Steward, and Baldwin, and in two cases reported by P. Ernst. This bacillus was found in a case of emphysematous gangrene of the hand reported by Mann. It is probably identical with the bacillus found by E. Fraenkel in four cases of emphysematous phlegmon reported in 1893, and called by him *bacillus phlegmones emphysematosæ.* It has been found by the writer in three cases of perforative peritonitis. It may cause emphysema of the subperitoneal tissues. It is probably a rather widely distributed bacillus.

Bacillus Diphtheriæ.—Observed by Klebs (1883), first cultivated and accurately described by Löffler (1884). Straight or slightly curved rods, averaging 1.2 to 2.5 μ in length, characterized especially by irregularities in shape and staining. Particularly characteristic are swollen ends and deeply-staining chromatin-granules in the bacilli. Stains by

Gram. Not motile. Does not form spores. Facultative anaërobe. Optimum temperature for growth 33–37° C. Grows only slowly and slightly, if at all, below 20° C. Grows on all alkaline culture media, invisibly on potato, best on Löffler's blood-serum bouillon mixture. Does not liquefy gelatin. Forms on agar grayish-white, granular colonies with slightly irregular margins. In bouillon grows in the form of small grayish particles, with or without clouding of the medium, often with formation of surface membrane. Particularly important as a diagnostic criterion is the change of the alkaline to acid reaction by forty-eight hours' growth in bouillon containing carbohydrate. Thermal death-point, 58° C. in ten minutes. May survive in some culture media eighteen months, but may die in three or four weeks. Lives longer in the dark than when exposed to light. Resistant to desiccation. May survive for three to five months in dry membranes, but usually dies sooner. Cultures dried on threads survive three to four weeks at room temperature. Both virulent and non-virulent diphtheria bacilli occur, the latter rarely in diphtheria. Pathogenic for many animals, and especially for guinea-pigs. By subcutaneous inoculation there is produced extensive local inflammation and necrosis. The animal dies usually in thirty-six to sixty hours, with necrotic foci in various internal organs and serous transudates in the serous cavities. The bacilli are found only near the seat of inoculation or in very small number in the organs. With less virulent cultures or smaller doses subacute and chronic infections or intoxications ensue. Genuine pseudo-membranes, as a rule with little tendency to spread, follow inoculation of mucous membranes superficially injured. The virulent diphtheria bacillus produces by its growth in cultures or in the animal body a powerful poison, called the toxin or toxalbumin of diphtheria, to which the constitutional symptoms, the lesions of internal organs, and the paralysis are due.

The diphtheria bacillus is the cause of all cases of genuine diphtheria. Similar pseudo-membranous inflammations of the throat and air-passages may be caused by streptococci. The intensity of the affection caused by the diphtheria bacillus varies from a slight inflammation without false membrane to the gravest pseudo-membranous inflammations.

The diphtheria bacillus is incapable of attacking the intact skin. It may, however, produce pseudo-membranous inflammations on excoriated, ulcerated, and wounded skin. Neisser has reported the case of a child five and a half years old with diphtheria of the throat in whom thick, firmly-adherent pseudo-membrane covered the skin about the anus over a space 10 cm. long and 4 cm. broad. There was œdema of the scrotum and penis. Löffler bacilli were found in the false membrane and throughout the infiltrated corium. The localization of the diphtheria bacillus in cutaneous surfaces which have been deprived of the epithelial covering by excoriation, eczema, ulceration, herpes, wounds, has been observed many times in persons affected with diphtheria of the throat, although it is not common. This localization may be attended by a pseudo-membrane, or by simple superficial necrosis, or by ordinary suppuration or inflammation in no way suggesting diphtheritis. Park found diphtheria bacilli in two cases in wounds of the finger received by physicians in intubating children with diphtheria. They persisted for six weeks in one case. Wright has demonstrated the presence of this bacillus in

excoriated or ulcerated surfaces of the skin in 7 cases, in paronychia in 1, in mastoid abscess in 1, in purulent conjunctivitis in 1,—all in cases of diphtheria. The diphtheritic process may extend by continuity to a tracheotomy wound. More frequently the wound is unaffected, even in cases where the diphtheria bacillus may be demonstrated upon its surface. Extensive necrotic and septic involvement of tracheotomy wounds is more frequently due to streptococci, with or without association with the diphtheria bacillus, than to the latter micro-organism alone. Brunner has reported three cases of infection of wounds with the diphtheria bacillus in association with pyogenic cocci in persons without demonstrable connection with other cases of diphtheria and without any affection of the throat. In only one case was there pseudo-membrane. The presence of the diphtheria bacillus was not suspected in any of these cases before the bacteriological examination.

In this connection a few words may be said regarding the general subject of wound diphtheritis, concerning which much confusion exists. Here, as well as in diphtheritis of mucous membrane, it is important to bear in mind that the term "diphtheritis" is a purely anatomical one, and implies nothing as to the causation of the affection. The term "diphtheria," on the other hand, should be restricted to the affection caused by the Löffler bacillus wherever this may be localized. There are three anatomical conditions of a wound to which the epithet "diphtheritic" has been applied—namely, first, the presence of an adherent fibrinous false membrane incorporated with underlying necrosis of the tissues; second, the presence of a fibrinous pseudo-membrane loosely attached to the underlying tissues, which may present no distinctive alteration; and, third, more or less extensive necrosis of the tissues of the wound without a distinct false membrane. Only the first condition is properly called diphtheritis; the second may be called simple pseudo-membranous or croupous inflammation, and the third is necrotic inflammation.

Wound diphtheria is infection of a wound by the Löffler bacillus. It may or may not be wound diphtheritis in the anatomical sense. Wound diphtheria may manifest itself as a simple inflammation, or inflammation with superficial necrosis, or inflammation with more or less adherent pseudo-membrane. Pyogenic cocci are usually associated with the Löffler bacillus in the diphtheria of wounds. Paralysis may follow wound diphtheria. As the same anatomical conditions in a wound may be produced by various causes, a positive diagnosis of wound diphtheria can be made only by bacteriological examination. The conditions as regards varying intensity and character of the infection, association with other bacteria, particularly streptococci, and the necessity of a bacteriological examination to establish the diagnosis, are in no way different in the diphtheria of wounds from those in diphtheria of mucous membranes. As has already been stated, wound diphtheria may occur without demonstrable connection with cases of diphtheria and without affection of the throat in the individual attacked, but such occurrences are rare.

Diphtheritic, necrotic, and croupous inflammations of wounds are caused most frequently by other micro-organisms than the Löffler bacillus. Here, as with similar inflammations of mucous membranes,

the streptococcus pyogenes appears to be an important causative agent, so far as can be judged from the small number of cases hitherto examined bacteriologically. In this comparatively rare class of streptococcus infection of wounds the intensity and extent of the inflammation vary within wide limits.

It is not, or formerly was not, a particularly rare occurrence for coherent false membranes to develop upon granulating surfaces without notable disturbance in the process of repair and without constitutional disturbance. The membrane in these cases can be readily stripped off, after which another membrane is likely to form. It has been proposed to call this relatively inoffensive wound complication "wound croup," in distinction from the more severe wound diphtheritis. In two cases of croupous membranes on granulations Brunner found the streptococcus pyogenes in pure culture. In similar cases he and Tavel have found also the bacillus coli communis in pure culture. The condition may doubtless be associated with the presence of various micro-organisms, and is not, therefore, a specific one. In croupous inflammations of fresh wounds Brunner found the streptococcus pyogenes in association with other pyogenic cocci.

How much the development of diphtheritic and necrotic inflammations of wounds is influenced by the general condition of the patient is shown by the greater frequency of its occurrence in persons prostrated with typhoid fever, scarlet fever, septicæmia, pyæmia, and other debilitating causes.

Diphtheritic inflammation of operative wounds involving the mouth and the bladder is more common than a similar affection of wounds in other parts of the body. The Löffler bacillus is not concerned, as a rule, with diphtheritis of these wounds, any more than it is with diphtheritic cystitis or enteritis.

Much interest attaches to the question of the causation of hospital gangrene, that frightful scourge of pre-antiseptic surgery in crowded hospitals, particularly in military hospitals. Hospital gangrene has been designated "wound diphtheritis," but it differs from the necrotic and diphtheritic inflammations of wounds, which are now occasionally observed, in many features, particularly by its phagedenic character and its mortality. It has apparently disappeared, at least from civilized countries, and there has been, therefore, no opportunity to make a bacteriological examination by modern methods of any case of this disease. Although some of the older writers identified the cause of hospital gangrene with that of true diphtheria, it seems, with our present knowledge, highly improbable that this is true. Our observations of the effects produced by the diphtheria bacillus with or without association with other bacteria in wounds do not indicate that this organism can have played any essential rôle in the causation of hospital gangrene. Some authorities are of the opinion that hospital gangrene is a specific infection due to a specific micro-organism which has disappeared from civilized countries, as the micro-organism of the plague has disappeared. It seems to the writer more probable that it was due to pyogenic bacteria which still exist, but which under the special conditions prevailing where hospital gangrene occurred had acquired a degree and kind of virulence with which we are no longer familiar. Thanks to antiseptic

surgery, these special conditions are not likely to be repeated in civilized countries.

Bacillus Tetani.—Observed by Nicolaier (1884) in wounds in cases of tetanus and demonstrated in garden earth, first obtained in pure culture by Kitasato (1889). Slender, straight bacilli, varying in length from short rods to long threads. Sluggishly motile. Spherical spores, thicker than the rods, develop at one end of the bacilli, giving them a drumstick or pin shape. Stains by Gram. Anaërobic. Grows best at body temperature, slowly at 18–20° C., not at all below 14° C. Spores are formed in cultures at body temperature in thirty hours, in cultures at 20° to 25° C, not until after a week. Grows in nutrient gelatin, which is slowly liquefied with slight gas production; in agar and bouillon when free oxygen is excluded. Growth in gelatin is fuzzy, radiating, like a thistle. Dried spores live months and years. Cultures containing spores dried on silk threads were found alive after several months by Kitasato. Henrijean demonstrated living, virulent tetanus spores on a piece of wood which had been extracted eleven years previously from the wound in a boy with fatal tetanus. The spores are killed in five minutes by moist heat at 100° C. They withstand in the moist condition for an hour a temperature of 80° C.—a property which was utilized by Kitasato to destroy other bacteria in obtaining pure cultures of the tetanus bacillus. The spores survive and preserve their virulence for ten hours in 5 per cent. carbolic acid; they are killed in fifteen hours. They are not killed by putrefactive bacteria.

The tetanus bacillus is more or less pathogenic for nearly all warm-blooded and some cold-blooded animals. Infection takes place only through a wound. The period of incubation varies from a few hours to several days, according to the susceptibility of the animal and the dose. Experimental tetanus corresponds in all essential particulars to human tetanus. Tetanic spasm appears first in the muscles nearest the seat of inoculation.

Tetanus is a toxic infection. The bacilli multiply only in the immediate neighborhood of the wound, and do not invade the blood and organs. Inoculation with pure cultures is a pure intoxication as a rule, with but little multiplication of the bacilli, so that at the autopsy it may be difficult to find any bacilli. When impure cultures and foreign bodies are introduced into the wound the bacilli are more readily demonstrable at autopsy. There are no demonstrable lesions of internal organs in experimental tetanus.

All of the symptoms of tetanus can be produced by the germ-free filtrate of tetanus cultures. It is the only infectious disease known every feature of which can be produced experimentally by injection of the poison without the micro-organisms. In the case of diphtheria all of the symptoms and lesions can be produced by the poison except the local false membrane. This requires the presence of the bacilli.

Brieger found in impure tetanus cultures four crystallizable alkaloidal substances belonging to the class of ptomaïnes. Three of these he called tetanin, tetanotoxin, and spasmotoxin. He found also an unnamed base. As these ptomaïnes produced spasms by injection into animals, this result was at first thought to indicate that the poison of tetanus had been isolated in a state of chemical purity. Subsequent investigations have

shown that these ptomaïnes do not reproduce all of the characteristic symptoms of tetanus. They are not the real tetanus poison, and no particular interest any longer attaches to them.

The real poison of tetanus belongs to a different class of substances—namely, the so-called toxic proteids or toxalbumins, substances about which we know very little chemically, but a great deal physiologically. We do not even know positively that the tetanus toxin is a proteid, but it is generally assumed to be. To this same class of substances belong the toxin of diphtheria, the venom of snakes, and certain poisonous substances produced by vegetable cells, as ricin, abrin, robin.

The specific tetanus toxin has been demonstrated both in cultures of the tetanus bacillus and in the bodies of animals. It has been found in the blood both during life and after death. It does not appear to be eliminated in appreciable amount by the urine unless very large doses are given. According to Kitasato, the poison is destroyed in the presence of water in five minutes at 65° C., in one and a half hours at 55° C; it stands drying at ordinary temperatures; is not injured by dilution with water or bouillon; is sensitive to acids and alkalies. It is destroyed by the acid gastric juice. It is injured by exposure to light. So sensitive is the tetanus poison to chemical reagents that Kitasato was unable to find any means of obtaining the poison in a condition approaching purity, and he expressed ignorance as to its real nature. Brieger and Cohn have, however, been more successful, and have isolated a substance possessing the properties of the tetanus poison in a condition approaching purity. As this substance was found to be without most of the proteid reactions, they consider that it is not an albumin in the ordinary sense of that term.

The tetanus toxin is of appalling potency. Kitasato obtained liquid cultures of such virulence that 0.00001 ccm. of the germ-free filtrate, corresponding to 0.00023 mgm. of the dried filtrate, sufficed to kill a mouse with tetanus. Of course only a part of the dried substance is the real poison. Of the purified substance obtained by Brieger and Cohn, who had at their disposal cultures of less primary virulence than those of Kitasato, 0.000,000,05 grm. killed a mouse of 15 grm. weight. As the fatal dose of the tetanus poison increases with much regularity in proportion to the weight of the animal, this would represent 0.23 mgm. as the fatal dose for a man weighing 70 kilo. When it is considered that the minimal fatal dose of atropine for an adult is 130 mgm. and of strychnine is 30–100 mgm., some conception of the terrible energy of this bacterial weapon can be obtained. The substance separated by Brieger and Cohn was not in a state of chemical purity. The tetanus poison, like the diphtheria poison, does not cause symptoms immediately after its introduction. With small doses it may be days before recognizable symptoms appear. This behavior is unlike that which we are accustomed to attribute to chemical poisons, and raises the question whether the poison may not be reproduced in the body, or whether the substance injected is itself the poison, and may not be in the nature of an enzyme which leads to the production of the real poison within the body. These questions cannot at present be answered.

An interesting example of the effect of the pure tetanus toxin upon man is reported by Nicolar. In working with the filtrate of a tetanus

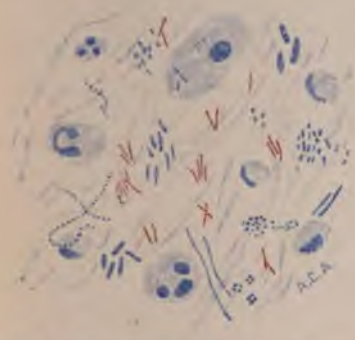
culture he accidentally stuck the point of the needle of a hypodermic syringe containing some of the fluid into his left hand. Only the moisture adhering to the needle was introduced into the puncture. After three and a half days the first symptoms of tetanus were manifested by contracture of the left thumb. There followed in succession contraction of the hand, the arm, then trismus, opisthotonos, general contractures, and convulsions. The treatment was by large doses of chloral. After three weeks improvement began, and recovery was complete after forty-one days. In this unique case the tetanus toxin was introduced in minimal amount without the bacilli. Nicolar, in view of the fact that no symptoms were manifested until the third day, adopts the view that the culture fluid does not contain the real poison, but produces it by a kind of fermentation after introduction into the body.

The distribution of the tetanus bacillus and the factors favoring infection with tetanus have already been described (pp. 253, 265, 276, and 289).

Susceptible animals may be rendered immune from tetanus by the injection of the tetanus poison, at first weakened by chemical agents or heat, and then administered in full strength in constantly increasing doses. This is antitoxic immunity, already described, which has nothing to do with natural immunity. The hen is naturally immune from tetanus, but not by virtue of any antitoxic power of the blood. The blood-serum and other fluids of animals rendered artificially immune from tetanus are capable, by virtue of their antitoxin, of rendering susceptible animals resistant to tetanus (passive immunity), or even of preventing the development of the disease or of curing the disease after reception of the virus. Behring in 1892 reported that in the course of two years he had by successive injection of increasing doses of the tetanus toxin rendered a horse so highly immune that the immunizing value of its blood-serum was 1 to 10,000,000, by which is meant that $\frac{1}{10000000}$th ccm. of serum will protect 1 grm. weight of mouse from the effects of the subsequent injection of the smallest fatal dose of the tetanus poison, or 1 ccm. of serum suffices to immunize 500,000 mice, weighing each 20 grams, or 200 sheep, weighing each 50 kilo. When, however, the attempt is made to prevent the development of the disease immediately after the reception of the virus, a larger quantity of the serum is required to afford protection than a few hours previously, and as time elapses the amount of serum required rapidly increases, until, as soon as the very first symptoms of the minimal fatal dose of tetanus poison appear in the mouse, one thousand times the quantity of serum necessary for simple preventive immunization must be injected. After twenty-four hours the necessary quantity of serum possessing an immunizing value of 1 to 1,000,000 is too great to be introduced into the animal. To produce the same curative effects in large animals as in small it is necessary to inject proportionately larger amounts, the dose being in approximately direct ratio to the respective weights of the animals. These considerations manifestly suggest serious difficulties in the application of the antitoxic treatment of tetanus to human beings. But there is another difficulty of probably greater force—namely, that we have no indication that tetanus will result from a wound in man until characteristic symptoms have appeared. By that time tetanus poison has accumulated in considerable amount in the system. Kitasato was unable to prevent the development of tetanus in mice by the com-

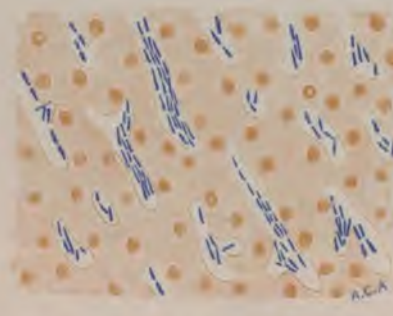
PLATE II.

FIG. 1.



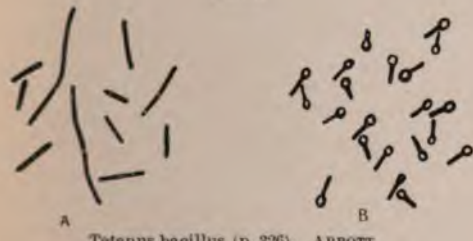
Tubercle bacillus and streptococci in sputum (p. 329). ABBOTT.

FIG. 2.



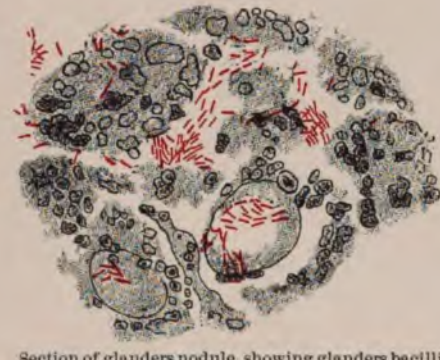
Anthrax bacillus in section of liver of mouse (p. 331). ABBOTT.

FIG. 3.



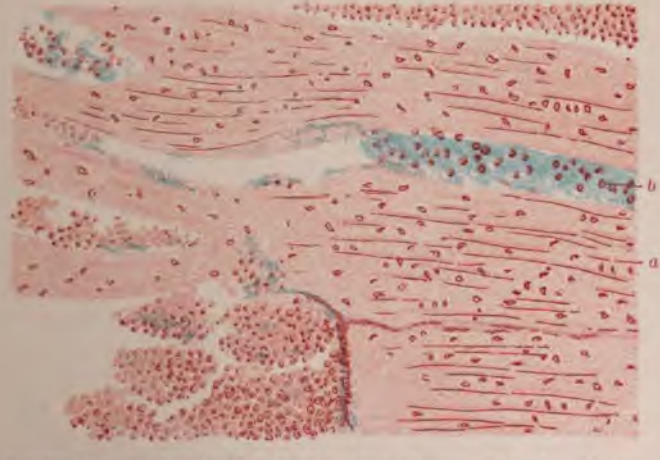
Tetanus bacillus (p. 326). ABBOTT.

FIG. 4.



Section of glanders nodule, showing glanders bacilli (p. 330). FLÜGGE.

FIG. 5.



Longitudinal section of rabbit's tibia showing osteomyelitis produced by intravenous injection of the staphylococcus pyogenes aureus. The cocci are colored blue. a, Compact tissue *of bone; b, Haversian* canal filled with staphylococci (p. 315). *LANNELONGUE and ACHARD.*

plete excision and thorough cauterization of the wound one hour after inoculation with tetanus bacilli. It is not positively proven that curative antitoxic serum neutralizes poison which has already been received into the system before injection of the serum, although it is capable of neutralizing poison formed after its administration. We stand in a much less favorable position for the successful treatment of human tetanus by antitoxin than is the case with diphtheria, where the conditions are more favorable both as regards progressive increase of dosage in proportion to the weight, and especially as regards the possibility of beginning treatment before the absorption of large quantities of the poison. These are the scientific considerations relating to the treatment of tetanus by antitoxin. Its practical application and the results of treatment in human beings belong to the article on Tetanus in this work.

Bacillus Tuberculosis.—Discovered and first cultivated by Koch (1882), independently and at about the same time demonstrated microscopically in tubercles by Baumgarten. Slender, straight, or slightly curved or bent, non-motile rods, 1.5 to 4 μ in length, which averages five to six times the breadth. In unstained specimens glistening dots, in stained specimens clear spots, are often seen in the rods, which thereby present a beaded appearance. These are interpreted by Koch and others as spores, but this has not been proven. No greater resistance to heat and other injurious agencies has been demonstrated for bacilli containing these suspected spores than for bacilli without them. Tubercle bacilli take up staining dyes with difficulty, but when once thoroughly stained by intense aniline dyes they retain the color after it has been extracted by acids, alcohol, and other decolorizers from all other known bacteria except the leprosy bacillus and some examples of smegma bacilli. (See p. 254.) It is by this peculiar staining reaction that tubercle bacilli are differentiated from other bacteria. The tubercle bacillus grows best in the presence of free oxygen, but is capable of growth without free oxygen. Optimum temperature for growth, 37 to 39° C. Does not grow below 29° C. Was first cultivated by Koch on solidified cow's blood-serum; has since been cultivated on potato, and on nutrient agar and bouillon to which 5 to 6 per cent. glycerin has been added. On blood-serum the growth first becomes visible after ten to fourteen days. It forms dry, lustreless, compact white scales, loosely attached to the surface. By coalescence of the colonies extensive membranous growths are formed. Grows in the form of a membrane on the surface of fluid media, without clouding the fluid. The tubercle bacillus is the most resistant to heat of all pathogenic bacteria not positively proven to form spores. The statements of different experimenters as to its thermal death-point are so widely divergent that bacilli from different sources, or at least under different conditions, would seem to vary in this respect; but it is more probable that the discordant results are due to failure to ensure exposure of the bacilli to the actual temperature of the surrounding fluid. The physical conditions as regards distribution of the temperature in heated animal fluids, culture media, etc., especially when solid masses are present, are not of so simple a nature as many of the experimenters upon the subject of the thermal death-point of bacteria seem to suppose. According to the careful experiments of Forster, tubercle bacilli are killed, or at least are rendered incapable of infecting guinea-

pigs, by ten minutes' exposure to a temperature of 70° C and by one hour's exposure to 60° C. They were not killed in forty-five minutes by heating to 60° C. They are surely killed in a few minutes by the boiling temperature. They retain their vitality in dried sputum for nine or ten months, but at the last with some loss of virulence. They resist putrefaction for a considerable time. They are killed in sputum by 3 per cent. carbolic acid in twenty hours; they are killed in a few minutes by 3 to 5 per cent. carbolic acid when the acid can come into direct contact with the bacilli. They resist the action of the gastric juice. When exposed in thin layer to the direct action of the sun's rays they are killed in a few minutes—much more slowly when in a thick layer.

The tubercle bacillus is a strict parasite, incapable under ordinary conditions of multiplication in the outer world, but capable of prolonged survival outside of the body. It is the sole cause of tuberculosis. The pathogenic manifestations of the tubercle bacillus have been described by Dr. Councilman (p. 239), and will be further considered in the articles treating of the various forms of surgical tuberculosis.

The bacillus of avian tuberculosis is a different species, or at least a different variety, from that of human tuberculosis.

Bacillus Leprœ.—Discovered by Hansen (1879) in leprous tubercles. Morphologically, the leprosy bacillus resembles very closely the tubercle bacillus, from which it probably cannot be distinguished in size and shape. It presents clear, unstained dots like those observed in tubercle bacilli. It resembles the tubercle bacillus also in its staining reactions, the only important difference being that it is more readily stained by aniline dyes than the tubercle bacillus. It stains well by Gram's and Weigert's fibrin stain. It is non-motile. Although many observers claim to have cultivated the leprosy bacillus, none of these claims have been established, at least not to the satisfaction of most bacteriologists. Most experimenters have had only negative results from the inoculation of leprous material into animals. The positive results reported by Damsch, Vossius and Melcher, and Ortman are open to criticism in their interpretation. The apparently successful inoculation of a condemned criminal in the Sandwich Islands by Arning has also been criticised as not conclusive. The constant and exclusive presence of the bacillus lepræ in leprosy cannot be reasonably interpreted otherwise than that the bacillus is the cause of the disease. The characteristic bacilli are present in enormous number in the leprous nodules, being chiefly enclosed within cells. They have also been found in the lesions of the disease in all parts of the body. They are very rarely in the blood.

Bacillus Mallei.—Discovered by Löffler and Schütz (1882) in the lesions of glanders. Somewhat shorter and thicker than the tubercle bacillus. Presents often clear, unstained spaces in the rods. It probably does not form spores. Decolorized by Gram. Stains with the usual aniline dyes, but is so easily decolorized that its demonstration in sections is somewhat difficult. Like the typhoid bacillus, it occurs in the tissues especially in clumps. Non-motile. Facultative anaërobe. Grows best at body temperature, but is capable of growth at room temperature. Grows on all culture media, but, as has been shown by Theobald Smith, far better on acid (non-neutralized) than on alkaline media. Particularly characteristic is the growth on potato, on which the glanders bacillus

forms at first a translucent, amber-yellow layer, later a reddish-brown layer with discoloration of the potato. Growth on agar whitish, moist; if the medium be acid, thick and abundant. The virulence diminishes in successive generations in artificial cultures. The glanders bacillus may survive in the dried condition for three and a half months, but usually dies within two or three weeks. There are observations which indicate that it may survive for at least a year and a half in unoccupied, infected stables. By inoculation of horses with pure cultures glanders is produced. The bacillus is pathogenic for several species of animals. The guinea-pig and the field-mouse are particularly susceptible. White mice are resistant. The field-mouse dies from experimental inoculation usually in three or four days with acute infection and minute tubercle-like nodules in the spleen and liver. The lesions in the guinea-pig are most characteristic, consisting in a caseous ulceration at the seat of subcutaneous inoculation, which, however, is often absent; swelling and necrotic suppuration of the testicles; swelling and ulceration of the joints; and nodules in the spleen and liver, sometimes elsewhere. The best method of diagnosing a suspected case of glanders is to inoculate the material into the peritoneal cavity of a male guinea-pig. In four or five days, at the most in eight or ten days, the characteristic swelling and inflammation of the testicles can be detected. The bacilli are in the lesions, but scanty or absent in the blood. Mallein is a product derived from cultures of the glanders bacillus, and is analogous in its properties and uses to tuberculin derived from the tubercle bacillus. It is used for the diagnosis of glanders in animals, as tuberculin is used for the diagnosis of tuberculosis.

Bacillus Anthracis.—Discovered in the blood of animals affected with anthrax by Pollender (1849); also observed by Davaine (1850), Rayer (1851), and Brauell (1857). The studies upon the anthrax bacillus laid the foundation-stone of modern bacteriology. The bacillus is 1 to 1.5 μ broad and 3 to 10 μ long. It grows out into long threads made up of bacilli, the adjacent ends of which are sharply cut and slightly concave. Not motile. Stains readily with aniline dyes, including Gram's stain. Forms spores in the presence of oxygen, but never within the animal body. Grows at room temperature, best at body temperature; does not grow below 12° C. Grows on all culture media. Liquefies gelatin with moderate rapidity. Colonies on gelatin are whitish, often with fuzzy, irregular, hair-like projections. Similar bristle-like projections often characterize the growth in the line of puncture in gelatin and agar. Desiccated spores may survive for years. Anthrax spores are usually killed in four minutes by boiling temperature, but they vary in their resistance, and may withstand boiling temperature for twelve minutes (von Esmarch). Some anthrax spores are killed by 5 per cent. carbolic acid in two days; others survive for forty days. Various modifications of character of the anthrax bacillus can be produced by cultivation at high temperatures (42–43° C.) or by the addition of dilute antiseptics, the most important modifications being the production of an asporogenic variety of the bacillus and the loss of virulence. Any degree of attenuation of virulence can be produced down to complete loss. These attenuated cultures serve as vaccines to render animals insusceptible to anthrax. The anthrax bacillus is a facultative parasite. It is in the highest degree virulent for mice and

guinea-pigs, somewhat less so for rabbits. Sheep and cattle are the animals which suffer the most from the natural disease. Swine, dogs, and most birds are immune. Rats and pigeons are resistant, but not wholly insusceptible, to anthrax. Man does not rank among those highly susceptible to the disease. Infection may occur from the skin, intestine, or lungs. In small susceptible animals experimental anthrax is a septicæmia with abundant bacilli in the blood. In man anthrax usually occurs with localized inflammations at the seat of invasion (malignant pustule, intestinal anthrax, wool-sorter's disease). In some cases the disease remains localized; in others general infection and multiple localization occur.

Actinomyces, or Ray Fungus.—First recognized as a living organism by Bollinger in 1877 in actinomycosis or lump-jaw of cattle; observed in man in 1845 by B. von Langenbeck, whose discovery, however, was not published until 1878, when it was mentioned by J. Israel, to whom belongs the credit of first recognizing the ray fungus as a distinct microorganism pathogenic for man.

There are various species or varieties of the genus actinomyces, but we are able with our present methods to differentiate them from each other only imperfectly. Actinomyces hominis, which is probably identical with actinomyces bovis, is the only species which will be considered here. Authorities are not agreed as to the botanical position of this organism, but most writers now regard it as belonging to the group of the more highly-organized pleomorphic bacteria, and allied to cladothrix or streptothrix. Some, however, class actinomyces with the fungi.

Actinomyces is the cause of a chronic inflammatory affection, presenting sometimes the characters of an abscess, at other times more those of a tumor, with suppurating tracts and cavities. The presence of the parasite can usually be detected with the naked eye by finding in the pus small yellowish granules. These granules vary in size, shape, and color. They are usually described as about the size of a pin's head. They may be much smaller, even microscopic in size, and exceptionally they may be massed together in clumps the size of a pea. To the naked eye they generally appear round, but microscopically their contours are seen to be irregular. They may be grayish and translucent like sago particles, or opaque gray or white, or yellow, greenish-yellow, brownish, even black. Bostroem has demonstrated that these various tints depend partly upon the stage of development of the organism, the younger forms without club-like terminations being pale and transparent. The black granules have been observed only in intestinal actinomycosis. The consistence of the granules or colonies in their early stage of development is soft and gelatinous; later it becomes firm and compact, and it may become hard and gritty from deposit of lime salts in the old, degenerated colonies. The young, translucent bodies are most abundant in foci of rapid softening and liquefaction of the tissues. The number of the bodies present in the pus varies in different cases. They may be so few as to require long search to find them; usually they are numerous, and sometimes there are myriads of them.

These characteristic granules, visible to the naked eye, are colonies of the actinomyces or clumps of colonies. The youngest colonies are not visible to the naked eye. These consist of a central interlacing mass of

branching threads with radiating projections of threads. The most common and characteristic appearances are found in older colonies (called by the Germans "Drusen"). Here we find the centre of each colony composed of extremely fine interlacing threads and small round bodies resembling cocci, and the periphery made up of bulbous, club-like terminations of the threads. It is particularly this outer ring of radiating, club-shaped projections which gives to these bodies their most diagnostic feature. It requires careful study and differential staining to make out the real structure of the actinomyces bodies. Ordinarily, the central part of the colony appears simply as a confused granular and finely-filamentous mass. It has, however, been shown to consist of extremely delicate rods and threads, which branch dichotomously, and which, arranged somewhat loosely in the centre, become more densely interwoven and larger toward the periphery, and there pass in a radiating manner one into each of the swollen bulbs. This bulbous swelling appears to be due to an accumulation of a clear hyaline material in the sheaths of the fibres, and to represent only an involution or degenerative condition, not forming an essential part of the living structure of the parasite. The hyaline bulbs may present an appearance of concentric striation, and each one may break up into finger-like projections or have somewhat the appearance of a pine cone. They may become calcified. These are all degenerative changes. Both within and outside of the threads are seen round bodies like cocci, which are considered by Bostroem to be spores, but whose nature is undetermined. They may be very abundant, so that the central part of the colonies consists almost wholly of these round granules with very few threads. Cases of actinomycosis occur exceptionally in which there are no bulbous endings to the threads composing the colony. In addition to the colonies, numerous bacilli are often found scattered throughout the inflammatory nodules of actinomycosis. Pyogenic cocci are frequent secondary invaders in actinomycotic growths. Gram's and Weigert's fibrin stain and hæmatoxylin and eosin can be used to advantage in the microscopical study of actinomyces.

Many investigators claim to have cultivated the ray fungus. There is so much discrepancy in their descriptions of the characters and conditions of these cultures that we cannot recognize all of them as genuine cultures of actinomyces. Probably the most confidence is to be given to the cultures obtained by J. Israel and M. Wolff. They found that actinomyces grows best anaërobically and at the temperature of 35°–37° C. They used chiefly as their culture media nutrient agar and hen's and pigeon's eggs. The growth is slow and in the form of dry, small, projecting, irregular colonies, which are at first gray and translucent, and later opaque. On agar actinomyces grows chiefly in the form of rods—in eggs, in the form of interlacing, branching threads. Bulbous terminations of the threads are not observed in the cultures.

The majority of experimenters have obtained only negative results in attempting to produce actinomycosis experimentally in animals by inoculation of material containing the specific micro-organism. Bostroem in his elaborate article on actinomycosis considers all of the positive results reported up to the date of its publication (1890) as inconclusive. Since that date, however, several observers have reported more or less

success in producing the disease experimentally; and here, again, the results obtained by Israel and Wolff are the most noteworthy. They succeeded by introduction of their pure cultures of actinomyces into the peritoneal cavity of rabbits and guinea-pigs in producing small nodules in the peritoneum and spleen. These nodules contained typical actinomyces colonies with the bulbous rays. Further investigation is needed regarding the experimental inoculation of actinomyces.

Infection both of human beings and of cattle with actinomycosis has been often traced to the penetration of vegetable grains (wheat, barley, oats) or bits of vegetable fibre into the tissues. The portal of entry is frequently the mouth, particularly the neighborhood of the teeth, but it may be through a wound of the skin or through the mucous membranes of the throat, respiratory tract, œsophagus, intestine, or middle ear. It is not always possible to find the point of entrance, as this may heal completely.

Various clinical types of actinomycosis are recognized according to the seat of the affection, such as actinomycoses of the jaws and elsewhere about the head and neck, of the lungs, the pleura, the vertebræ, the intestine and other abdominal organs, the brain, the middle ear, the skin. There is usually a single localization, but there may be multiple foci, presenting sometimes anatomical and clinical characters of pyæmia.

The histological changes are characterized by necrosis and liquefaction of tissue with emigration of white blood-corpuscles as the immediate effect of the parasite, and a secondary reactive inflammation in the form of vascular granulation tissue. By some the changes are considered to be more closely allied to those of infectious granulomata than of ordinary inflammation. In some cases the process is rapid and destructive, with little new formation of tissue, and with the production of large abscesses; in others the affection may be very chronic, of limited extent, and encapsulated by new growth of tissue. When bone is involved there may be formed osteophytes and sclerosing ostitis, or there may be simply destruction without new formation of bone. Metastases do not appear to occur in the lymphatic glands communicating by the lymph-current with a primary focus of actinomycosis.

Madura disease, or mycetoma, both in the melanoid and the ochroid varieties, has been shown by Kanthack to be due to a parasite very closely allied to the ordinary actinomyces hominis. Kanthack considers that the parasite is simply a variety of the ordinary actinomyces.

SYMPTOMS, DIAGNOSIS, AND TREATMENT OF INFLAMMATION, ABSCESS, ULCER, AND GANGRENE.

By CHAS. B. NANCREDE, A. M., M. D.

Inflammation is "the succession of changes which occur in a living tissue when it is injured, provided the injury is not of such a degree as at once to destroy its vitality, these changes tending to the repair of tissues or the neutralization or removal of the primary microbic cause."

This definition indicates that there are two distinct forms of inflammation. The first is a purely regenerative process, which, occurring in aseptic tissues, is productive of cell-proliferation, these new cells developing into a normal, permanent tissue. It must never be forgotten that the processes of inflammation are essentially the same in the vascular, the soft and the hard, the superficial and the deep tissues.

Acute Simple or Plastic Inflammation.

Because this is a purely regenerative process some contend that it should not be described as a disease. While this is partly true, aseptic inflammation must be here studied, not only because at the outset microbic inflammation presents similar microscopic and macroscopic phenomena, and, when recovery ensues, healing occurs by the same histological changes, but also to learn how microbes interfere with regeneration, and how the surgeon can minimize their malign effects when he cannot wholly exclude them.

Redness, heat, pain, swelling, and impaired function, the classical symptoms of inflammation, can rarely be all detected except when the superficial parts are affected. The redness, at first uniform, fading into the hue of the surrounding healthy parts, temporarily disappears on pressure, but later becomes mottled with patches of a deeper hue which are uninfluenced by pressure. The uniform tint is from excess of blood in the vessels, while the mottling results either from the diapedesis of red cells, their escape by rupture of the capillaries into the tissues, or from clotting (thrombosis) of blood in the vessels; hence pressure influences the first, but not the second, condition. To this excess of blood is also due the increased temperature of the part, although some allege that chemico-vital phenomena account for part of the heat: it is doubtful if the temperature of an inflamed part is ever higher than that of the blood in the heart of the individual, in whom, it must be remembered, the whole mass of the blood is warmer than in health because of the *febrile heat*. Swelling also is at first due to

excess of blood, but soon the distended blood-vessels permit the escape of serum, then liquor sanguinis and leucocytes, the latter migrating through the vessel-walls by virtue of their amœboid movements. At the periphery of the inflammation little but serum or some liquor sanguinis distends the tissues, which, if the part be superficial, gives rise to the symptom œdema—*i. e.* the tissues remain pitted for some time after firm pressure has been made, and the part is often paler than normal. This succulence of the tissues has been experimentally demonstrated by examining the amount of fluid returned by the lymphatics leading from an inflamed area, as compared with that poured out when the vessels of the corresponding member were divided: the neighboring lymphatic glands are often enlarged and tender from the passage of this excess of lymph, which contains irritating materials. Pain results from the stretching of the nerves due to swelling, from their compression by exudates, their exalted sensibility from increased vascularity, and from the chemical irritation of ptomaïnes or toxalbumins when present. As the microscopic phenomena of inflammation are described elsewhere, it is only necessary to advert for clinical purposes to certain points—viz. that after the primary acceleration of the blood-current a gradual "slowing" of this occurs, allowing germs as well as leucocytes to accumulate in the circumferential colorless current; that from this time on the white blood-cells migrate in increasing numbers until the focus of inflammation is crowded with leucocytes—indeed, the cell-islets of the tissues are practically replaced by the migrated white blood-corpuscles, with a varying number of red cells; that next stasis of the blood-current occurs, but that if the exciting cause of the inflammation ceases all these processes will be reversed, for the blood which is at rest *is not clotted*. Thus the central mass of red cells first oscillates, then the current commences, the white cells slowly mingle with the central column of red cells, the migrated leucocytes pass off through the lymphatics or disintegrate, and their remnants are disposed of by the same route, together with the excess of fluid, the parts being left in their normal condition.

When these changes are rapidly effected the inflammation is said to terminate by "delitescence;" when the tissues have to be cleared of the migrated cells by their disintegration, "resolution" is the term employed for this slower process. Should these favorable changes not take place, permanent stasis must occur, thrombi forming in the vessels; the effused liquor sanguinis coagulates in the tissues, and the inflamed area, from the combined effect of the original injury, plugging of its vessels, accumulation of fluids and of cells, is deprived of proper nutriment and disappears by absorption, leaving nothing but a mass of young cells held together with a small amount of intercellular cement. That this cellular mass may develop into permanent tissue, its due blood-supply must be furnished, which comes by the ingrowth of capillary loops springing from the blood-vessels of the surrounding undamaged tissues: in other words, fully-formed granulations are formed. When the bulk of the cells develops into fibrous tissue a subcutaneous scar results, with its ulterior evil effects, but when less scar-tissue forms, and it is somewhat diffused throughout the part, the condition is termed "fibroid" or "chronic" thickening.

If during the first stages of inflammation, when the vital resistance is

lowered, microbes reach the tissues, an infective inflammation will result, but if their advent be delayed until the second stage, that of fully-formed granulation tissue, be reached, microbic invasion is always vigorously, and often successfully, resisted. When the so-called third stage of inflammation has been attained—*i. e.* that of a mature but low-grade tissue, possessing for the time an excessive vascular supply—microbes can exert no more harmful influence than upon any other similar tissue.

Infective Inflammation.

This is a result of the interference produced by microbes with the processes of repair always attempted by nature, and the products of tissue-metamorphosis do not undergo development into a permanent tissue, but suffer from degenerative changes. Either the ptomaïnes, peptonizing ferment, or certain toxalbumins are the direct causes, not the germs themselves. These substances produce coagulation-necrosis, directly or indirectly solution of the intercellular cement binding the exudate together, and the fatty degeneration and death of the cells, these latter being gradually absorbed after cessation of the cause, as in certain cases of tuberculosis, or, dying more rapidly, mingle with the pus-cells which float in the liquefied intercellular cement mingled with the serous exudate—*i. e.* the *liquor puris*.

Suppuration is now said to be established. When this occurs upon a free surface, as that of the skin or a mucous membrane, with loss of substance, the process is termed "ulceration;" the resultant loss of substance, an "ulcer." Occurring distinctly circumscribed in the depths of the tissues, it is called an "abscess," or when not so sharply defined from the surrounding tissues, a "purulent collection." The pus being evacuated by nature or art, if death does not result from absorption of ptomaïnes or toxines, the parts revert to their normal condition, except where the tissues have been destroyed in the suppurative process: here a scar composed of newly-formed connective tissue forms.

The rapidity with which the inflammatory process passes through its various phases—*i. e.* whether it is acute, subacute, or chronic—depends first upon the nature of the micro-organisms causing it. Thus infection by the ordinary germs of suppuration or by those of gonorrhœa produces an acute process; the germs of glanders induce a subacute or chronic inflammation, while those of tubercle produce a chronic inflammation. The number of any form of germ present influences the rapidity and severity of the inflammation, for healthy tissues can inhibit the growth of, or entirely resist the action of, and remove, germs, if not too numerous. A few of the minute processes must be briefly reviewed in order to understand microbic inflammation.

The primary acceleration and increased volume of the blood-current prevent mural implantation of germs or sweep away such as have become attached to the vessel-walls. During the second stage—*i. e.* that of the formation of granulation tissue—this process is successfully carried out *around* the primary infected area, but the peptonizing ferment or the ptomaïnes destroy this boundary-area, and continue to do so until the virulence of the cause is exhausted. Then the last-formed granulations, surrounding the pus or the specific tissue, produce healing of the cavity

after the pus or liquefied tissue with the germs has been evacuated. In certain instances of chronic infective processes, as tubercle, under favorable conditions, retrograde processes do not occur, the embryonal cells becoming converted into scar-tissue.

Certain microbic processes, such as tubercle or acute osteomyelitis, are not commonly excited by severe injuries, but by slight ones producing a *locus minoris resistentiæ*. The increased afflux of blood induced by a severe injury, and the cellular exudate, some of whose elements are doubtless phagocytes, probably explain this. Again, the numerous white cells by their power of incorporating foreign bodies serve to remove after such injury germs which are destroyed by the nucleins of the blood or are excreted by the kidneys. The imperfectly vascularized granulation tissue resulting from such chronic infective inflammations as actinomycosis, tubercle, etc. predisposes to suppuration by preparing a soil for secondary infection with pyogenic organisms.

To recapitulate: the terminations of inflammation are, for the plastic variety, delitescence, resolution, and fibroid thickening; for infective inflammations, suppuration or ulceration. Gangrene is not a *termination* of any form of inflammation, but a consequence and an accidental result of the inflammatory process.

The old view, that inflammation involved an increase in the nutritive activity, is no longer tenable for the infective forms, lowered vitality being the predisposing cause, and, later, the efficient cause of their continuance and spread: this fact is the key to their treatment.

Inflammation is primarily a molecular change which may be due to microbic ferments, ptomaïnes, or toxalbumins circulating in the blood, or to traumatism so damaging the tissues that the changes of a plastic inflammation will result; or, from the physical conditions produced, germs, entering elsewhere, will accumulate, producing some variety of microbic inflammation.

Precisely similar injuries inflicted upon different individuals, or upon the same individual before and after an attack—say, of rubeola[1]—will produce in one instance nothing but a plastic process, in another a grave microbic inflammation. Precedent conditions which of themselves are incapable of producing evil in the absence of some exciting cause, as a blow or wound, thus favor the production of inflammation; these conditions are termed *predisposing causes*. They act by so lowering the vitality of the parts as to render them unable to resist deleterious influences. Among the most common are the impoverishment of the blood and the weakened heart's action resulting from insufficient or improper food, the former lowering the tissue-resistance to microbes, the latter so slowing the circulation as to favor the accumulation of germs. The acute anæmia and weakened heart produced by hemorrhage act similarly. The weak heart-action often seen in old age favors stasis, and thus accumulation of germs if any gain access to the circulation, which the ill-nourished

[1] It is important to remember that not only is inflammation modified by certain eruptive ailments, but also that inflammation following operation may predispose to them. Thus, scarlatina sometimes promptly follows upon operation where no known exposure has occurred, the lowered somatic vitality favoring the development of the eruptive disease. Of course reference is not here made to the scarlatinoid eruptions of sepsis, but to the genuine eruptive fever, scarlatina. For the pseudo-scarlatina the reader is referred to the section on Septicæmia, etc.

tissues cannot resist. The depravation of the blood by the retention of the excreta in chronic renal and hepatic diseases, as well as in gout, syphilis, and diabetes, predisposes to inflammations. The vasomotor disturbances following certain nerve-injuries lead to such imperfect nutrition and tendency to stasis that, as is well known, inflammation readily occurs. The relation of the so-called strumous diathesis is difficult to understand unless upon the assumption that in some individuals there exists a tendency to excessive cellular proliferation upon trivial injury. The numerous cells so outstrip their nutrient supply that caseous degeneration is prone to occur, providing an excellent culture-medium for the germs of tubercle primarily, and for those of pus later.

The exciting causes of inflammation are usually stated to be direct violence—*i. e.* mechanical injuries—heat, cold, electricity (as a cauterizant), tension, acids, or alkalies; but violence *per se* can only induce primarily a plastic inflammation, nor will the other agencies do more unless infection by micro-organisms ensues; so that the only exciting cause for inflammations which are not simply the conservative processes of repair (*i. e.* plastic inflammation) are the ptomaïnes, peptonizing ferments, or toxalbumins resulting from the development of micro-organisms, direct violence being relegated to the category of *predisposing* causes. That healthy tissues can inhibit the growth of or destroy numerous bacteria must never be forgotten, this truth reconciling many apparently contradictory facts as to the relation of micro-organisms and inflammation.

A broad distinction must be made between the micro-organisms of putrefaction and those which are infective or pathogenic, the former living only in dead or dying tissues and generating various poisonous ptomaïnes, the latter capable of developing in living tissues, thriving in the innermost recesses of organs if carried there by the lymph or blood, and producing wherever located each its special ferment, toxalbumin, etc. The entrance-point, or "infection-atrium," is usually a wound, especially a foul, ill-drained one, but germs may enter through trivial lesions of the cutaneous, respiratory, or alimentary tract.

Treatment.—This should be preventive when feasible: the appropriate measures will be found in the section on the aseptic and antiseptic treatment of wounds. The curative treatment must first aim to remove the secondary causes which maintain the process, and next to minimize the inevitable damage. Rest in its widest sense must be secured—by quiet of the parts obtained by splints or other dressings; by the drainage effected by incision and position, thus securing undisturbed contact of healing parts; by relief of tension, effected by the preceding measures supplemented by incisions other than those for drainage; by lessening the force and frequency of the heart's action; by diminishing the blood-supply by local astringents; by evacuation of irritating materials, as putrid urine, blood, or pus; by the use of non-irritating dressings; and by the recognition and treatment of such predisposing conditions as rheumatism, syphilis, gout, and tubercle. If these measures do not result in the subsidence of the inflammation, the second indication—viz. to lessen the extent of the inevitable damage—must be carried out by measures adapted to improve the nutrition of the tissues, thus preventing local or somatic death.

The abnormal blood-pressure maintains the dilatation of the vessels

and the accumulation and escape of liquid and solid exudates, which by their mechanical pressure on the tissue-cells interfere with their nutrition. A lessening of the blood-supply will diminish all this and the tendency to stasis. The measures already detailed will effect much, but especially treatment of the dyscrasia acting as a predisposing cause. Pain must be relieved, because it can alone increase local vascularity, induce rise of temperature, prevent sleep and ingestion of food, thus directly lowering vitality; moreover, severe pain maintains shock and probably actually kills the very old or very young. The rapidity of cure is often dependent upon the relief of pain and irritation. A close watch must be kept upon the action of the kidneys, skin, and liver—viz. the emunctories. While too free movements of the bowels must be checked, in septic conditions this attempt of nature to evacuate peccant matters must be most cautiously interfered with.

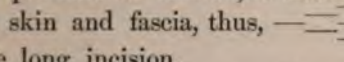
From what precedes it is evident that both local and general measures are available, the former sometimes being alone requisite.

Local Measures.—Rest, complete and physiological, must be maintained. Elevation of the part, by interfering with the access of arterial blood, favoring the egress of venous blood, and aiding drainage by the lymphatics, is very useful. Cold is effective, but demands caution, and is best used as a preventive before stasis has taken place, although later it may do good by lessening the congestion at the periphery, even when stasis has occurred at the focus. It is usually only harmful in the later stages, especially if strangulation of the tissues exists, when cold may determine mortification.

As cold can only act through the vasomotor nervous system, first causing contraction of the arterioles, then of the capillaries and veins, indirectly relieving intravascular pressure, it is only necessary to impress the sensory nerves of the part by moderate cold, because intense cold directly lowers the vitality of the tissues and promotes adhesion of the leucocytes, precipitating stasis, as occurs in frost-bite: moderate cold doubtless renders the amœboid action of the leucocytes more sluggish, thus opposing diapedesis. To be effective it must be continuous. As moist cold, water at the proper temperature can be allowed to drip on the parts —covered with lint or cotton to diffuse the fluid over a wider area—or can be conducted to this covering from the vessel by capillarity, using strips of lint or gauze. The water may contain any germicide desired, this measure being often desirable if suppuration is present. Dry cold can be applied by ice-bags or bladders or by Leiter's coils, which can be extemporized out of a few yards of small rubber tubing wired into shape or sewed to a piece of muslin.

Heat possibly acts derivatively by dilating the peripheral capillaries and those of the skin, but the chief benefit derived from its use is that, when suppuration cannot be avoided, it hastens the process, tending to localize it by promoting the flow of blood and stimulating the amœboid action of the leucocytes, causing their rapid accumulation at the focus of inflammation. When resolution is possible the increased blood-supply caused by the application of heat favors absorption of the liquid exudates, and the increased amœboid activity of the wandering cells enables them to migrate through the lymph-spaces, thus clearing the tissues of the solid exudate.

Heat may be employed dry by hot-water bags, by bottles, by heated bags of salt, or by Leiter's tubes; moist heat can be employed by irrigation or by some form of poultice—*i. e.* some coherent substance, as flaxseed meal, cotton batting, etc., which will retain heat and moisture. Poultices, other than wet absorbent antiseptic dressings covered with oiled silk or rubber tissue, should never be employed after a suppurating focus has been opened or when Nature may evacuate this at any moment, since asepsis would be impossible.

Bloodletting.—To be efficient, this must deplete the vascular area involved, even at a distance. Thus, blood drawn over the temples is removed from veins which communicate with the ophthalmic vein; leeches over the mastoid process abstract blood from the radicles of the mastoid vein, which empties directly into the lateral sinus. Local bleeding can do good only in the earlier stages of inflammation, when stasis is about to occur or has just occurred—*i. e.* before thrombosis has taken place. Employed at this stage, the stagnant blood can be seen to resume its flow through the occluded vessels, and a rapid reversal of the inflammatory processes takes place.[1] Leeching or cupping is the best means for the local abstraction of blood. Incisions are useful to relieve mechanical tension, to give vent to exudates, and to remove the constricting effects of tense skin and fascia. The escape of ptomaïnes and toxalbumins in the exudate, whose absorption is favored by the extravascular pressure of tension, is another benefit. Many short incisions through skin and fascia, thus,  , will relieve tension better than one long incision.

As inflammation is almost solely a vascular process, it may be proper to starve it, as it were, in rare instances, by pressure upon, or ligature of, the main vessel of the part.

Astringents are possibly useful at the very outset, when the primary vascular dilatation is commencing, but are better employed during the terminal stages of certain inflammations of the mucous membranes of the mouth, nose, urethra, conjunctiva, etc.

Certain drugs possess a limited value. Thus purgatives deplete, excrete ptomaïnes and toxalbumins, revulse, and are indicated in orchitis, gonorrhœa, and septic peritonitis. Diaphoretics and diuretics do to a less extent what purgatives effect, and also lower temperature. Remedies lowering the cardiac frequency and force are beneficial only at the outset, while later digitalis, quinine, and alcohol are requisite to sustain the heart. Auscultation of the heart to ascertain whether the first sound is normal or weakened is more to be depended upon than the character of the pulse. Opium relieves pain,[2] prevents exhaustion from loss of sleep, and contracts the peripheral capillaries: except in children it is best given hypodermically. Excessive febrile heat, dangerous at any age to the heart and nerve-centres, but especially in the young and the old, often causing in the former convulsions, should be moderated by quinine,

[1] See author's paper in *Transactions of Amer. Surg. Association*, vol. i. p. 185, "Have we any therapeutic means, as proven by experiment, which directly affect the local processes of inflammation?"

[2] Care should be exercised lest two evils follow: first, checking of the secretions so essential as a means of elimination, and the induction of morphinism when the case requires prolonged treatment.

diaphoretics, sponging, and the cautious use of antipyretics. If any constitutional vice be detectable, as gout, rheumatism, or syphilis, appropriate remedies must be given. When nervous symptoms are pronounced in drinkers, chloral and the bromides are indicated to prevent delirium tremens.

Constitutional Treatment.—There is no special treatment for inflammation. If the bowels are confined, give a laxative, preferably calomel, followed by a saline, when from over-eating, sedentary habits, or drink the liver acts inefficiently, not because mercury has any specific action, but because it is acceptable to the irritable stomach so often present and is an intestinal antiseptic. Under such circumstances moderately restrict food and drink, but never alter a patient's habits unnecessarily. In all cases get the history of the patient. If underfed, feed up; if overfed, restrict the diet. If alcohol is used, ascertain the form and quantity, and employ the minimum requisite to keep the patient from running the risks of the total withdrawal of stimulants; a gin-drinker will not do well on champagne, nor a beer-consumer on whiskey. In malarial neighborhoods quinine is usually advisable. In the young and vigorous less food than usual, and that of an easily digestible nature, must be employed at the outset, but the feeble, in whom an asthenic type of inflammation is apt to prevail, should receive from the beginning as large quantities of easily digestible food as can be assimilated.

Chronic Inflammation.

The pathological processes are essentially the same as in acute inflammation, the vessels remaining dilated with continuous escape of leucocytes and liquor sanguinis, which stimulate growth and excessive proliferation of fixed connective tissue, and possibly other cells. The *causes* are the same as for the acute process, but they act more slowly and with less intensity. Passive congestions, the strumous, rheumatic, or gouty diathesis, with constitutional syphilis, often serve as predisposing causes. The exciting causes are often so trivial as to be overlooked, but secondary causes maintain the inflammation. Thus the tension from synovial effusion produced by the use of a joint in a rheumatic person after a slight injury may keep up trouble for years. Unsuspected latent tubercular foci may give trouble only after over-exertion or a slight traumatism has so increased their vascularity that renewed growth and continuous extension occur.

Symptoms.—The redness, if present, is dusky; there is apt to be pigmentation from the constant escape of red blood-cells. A dull aching, most marked at night, increased by pressure, or perhaps tenderness only, is complained of, rather than acute pain. While slight increase of heat may be noted, often there is no local rise of temperature. Swelling is always well marked and detectable if the part be not too deeply seated. Constitutional symptoms, as fever, are sometimes absent, especially if no important organ is involved, but the patient is usually out of health, and may present evidences of syphilis, rheumatism, gout, or tubercle. The possible terminations of chronic inflammation are resolution, suppuration, or ulceration, chronic induration or thickening, caseation, and calcification.

Treatment.—All secondary causes of irritation must be removed, the dilated vessels with their sluggish current promoting constant escape of leucocytes, and the formation of a low grade of interstitial connective tissue—*i. e.* scar-tissue—must be stimulated to contraction. The nutrition of the tissues should be promoted by the access of arterial blood and the free return of the venous blood, and means should be taken to promote the absorption of inflammatory exudates. Supporting pressure will reduce the size of the vessels and induce atrophy of the poorly-organized exudate. Massage will break down exudates, force the cells into the surrounding lymph-spaces, increase the arterial afflux, and favor the venous efflux. Alternate hot and cold douches are also valuable vascular stimulants. Counter-irritation by blisters, the actual cautery, etc. is of value if employed upon the contiguous vascular areas above or below the part, but can only prove harmful when applied to the part itself. Improvement of the general health by appropriate remedies and attention to any gouty, rheumatic, tubercular, or syphilitic taint is essential to success.

General Considerations.—Ulceration and Abscess.

These processes are always the result of microbic infection interfering with the normal processes of repair, the so-called "plastic inflammation," which results from the injury of aseptic tissues, provided their vitality be not at once destroyed. All suppurative processes are essentially destructive, resulting in loss of tissue. When such microbic inflammation takes place upon a free surface, as a cutaneous or mucous membrane, loss of substance occurs by molecular destruction of tissue, the processes which produce this being called "ulceration," and the resultant area of inflamed tissue which has suffered loss of substance is called an "ulcer."

All ulcers heal by the organization of granulations which become covered by epithelium. When primary union fails or when sloughing results from traumatism, the term "ulcer" is applied to any granulating surface left, because healing takes place by the same processes. Although the pathology of inflammation and suppuration will receive extended notice elsewhere, it is essential here to describe briefly certain portions of these processes, that the reader may comprehend what follows.

From the presence of microbes at the outset, or because of their secondary implantation at the focus of inflammation, the tissues at this spot become so crowded with exudates that they are practically replaced by masses of young cells, and the vessels are thrombosed, so that a return to the normal state is impossible unless a new vascular supply enables the cells of the exudate to develop into a permanent tissue. In the normal reparative processes nutriment from the surrounding vascular areas reaches the most centrally located cells, passing from cell to cell or between them, the cells being held in contact by the intercellular material until vascular loops interpenetrate the exudate.

The presence of microbes changes all these processes. The resultant peptonizing ferments or the ptomaïnes either attack the vitality of the cells, or, by disassociating them by dissolving the intercellular cement, put them into condition to undergo fatty degeneration, to die, and to become suspended in a fluid, the *liquor puris*, composed of exuded serum, liquefied intercellular cement, and exudate. When these processes are very

rapid small areas of tissue become surrounded by others so thoroughly infiltrated with cells that upon their solution into pus these comparatively unaltered fragments are seen floating as shreds in the pus. When this occurs upon a free surface a variety of sloughing ulcer results. While many forms of microbes have at times proved to be pyogenic, the most common varieties found in acute abscesses are the *staphylococcus pyogenes aureus* and *albus*. The fact that these germs tend to aggregate into clusters (hence their name) would seem to explain the circumscribed character of the suppurations they initiate. A marked difference is usually noticeable in purulent conditions induced by streptococci. These germs rapidly become diffused through the tissues by way of the lymphatics, and are therefore apt to originate diffused suppuration.

That microbes are the cause of suppuration would seem to be contradicted by the occasional failure to find them in cold abscesses, but the explanation of the apparent exception is twofold: either that they were present earlier, but died from lack of pabulum or self-poisoned by their own excreta, or that in the given instance the tubercle bacillus acted as a pyogenic organism; which is unquestionably, although rarely, true. Again, however closely it may resemble pus, the fluid contained in many cold abscesses is not pus, but liquefied caseated tubercle, no pus-cells being discernible. Local suppuration can be promptly and certainly produced by the inoculation of ordinary pus-germs, as by rubbing pure cultures into the intact skin. The fluid resulting from the injection of aseptic chemical substances, such as turpentine, croton oil, etc., is *puruloid*, but is not *pus*. It is merely a fibrinous exudate containing numerous cells; is only seen when exceptionally favorable laboratory conditions are secured; shows no tendency to spontaneous evacuation, as true pus does, because the solvent action of the peptonizing bacterial ferment is absent, which also prevents the coagulation of new exudate; and finally, is never found clinically. Again, the injection of a ptomaïne into the tissues merely reproduces the conditions which would be furnished if bacteria were present.

Predisposing Causes.—Abscess being a result either of primary or of secondary microbic inflammation, those conditions which experience has shown to predispose to this variety of inflammation must favor pus-production. Local conditions which lower the vitality of the tissues, and general impairment of nutrition, however effected, favor microbic inflammation. Temporary slowing of the circulation from accidental causes, especially when aided by anatomical conditions, favors localization of microbes. Thus a trivial contusion of the medulla of bone, rupturing a few vessels in which thrombi form, produces a collateral hyperæmia which produces a slowing of the circulation, so that mechanically—being heavier than the blood-cells—the germs accumulate. The tortuosity of the medullary vessels, and in consequence the sluggish current flowing through them, favor microbic implantation, so that exposure to cold, driving the blood from the surface, may cause such additional dilatation of the vessels as to determine an accumulation of germs if they have gained access to the circulation by any distant infection-atrium.

General Symptoms of Abscess.—Pus-formation is so often preceded by a chill or rigor that when this occurs during an attack of local-

ized inflammation it is too commonly viewed as a conclusive symptom, especially if the fever which results is followed by a second chill. This idea is erroneous, as in some individuals, especially when certain parts or organs are involved, the chill may be only indicative of the thorough establishment of the inflammatory process or the sudden involvement of a new area: again, all malarial poisoning must be excluded. Fever will be present in varying degrees, with its concurrent anorexia, coated tongue, dry skin, confined bowels, and scanty urine. In some individuals delirium may be present; but all these symptoms, it must be remarked, are not those of abscess specially, but of the inflammatory process which is terminating in suppuration.

As the thoroughly infiltrated focus dissolves into pus the peripheral area, just about to be converted into granulation tissue by the ingrowth of capillary loops, is attacked by the ingrowing germs and their solvent products, and breaks down into pus, thus enlarging the abscess-area. This futile attempt at the formation of granulations usually goes on until nature or art evacuates the abscess, when, the tension being relieved, the excessive vascularity disappears, the peripheral layer of granulations becomes perfected, the cavity collapses, the apposed surfaces fuse, and, epidermis forming over the skin-orifice, cicatrization is completed, the granulation tissue becoming converted into connective tissue; *i. e.* a subcutaneous *contracting scar* forms.

When the processes are slower, or from any cause the pyogenic organisms lose their virulence, the peripheral layer of infiltrated tissue becomes converted into granulation tissue, but from the non-evacuation of the pus is prevented from fulfilling its normal function—viz. conversion into fully-formed but low-grade connective tissue; this process stops halfway, the deeper layers undergoing this change, while the superficial remain here and there as scattered, ill-formed granulations: this membrane-like structure is the miscalled pyogenic membrane.

Acute Abscess.

The causation, pathology, and method of healing must be sought in the section on Inflammation.

Symptoms.—During an acute inflammation the process becomes more localized at one point. Throbbing pain is felt, and a chill often occurs when pus forms. If superficial, the inflammatory redness and swelling become more circumscribed; palpation discovers central softening and fluctuation: this spot becomes more prominent—*i. e.* pointing takes place. The skin, becoming purplish, glazed, and thinned, gives way, either after the separation of a slough or by ulceration following the formation and rupture of a bleb of cuticle. A deep-seated abscess is shown by œdema, mottling of the skin, tenderness, and localized induration, or a sense of resistance of the deeper parts, with obscure fluctuation; fever, and probably rigors, having preceded these symptoms. When in doubt the grooved needle must be employed.

Treatment.—Up to the time of incision or rupture warm poultices will hasten the process and limit its extent, but when about to be spontaneously evacuated moist antiseptic dressings must be substituted. Pus should always be early evacuated by incisions made at the most depend-

ent part to facilitate drainage if no important structures are in the way. Such incisions must be free, and should be followed by the introduction of drainage-tubes. Sometimes counter-openings are advisable. Pus ought to be allowed to *flow* away, because pressure will rupture granulations, the only barrier against absorption of noxious products. Subsequently, antiseptic dressings must be used—never a poultice. Pus is always destructive, causing absorption of the tissues as it pursues the line of least resistance, and may open into joints, mucous canals, etc.; hence, when in the perineum, near the peritoneum, in a tendon-sheath, beneath tense fascia, or compressing a canal, as the trachea or urethra, especially prompt intervention is demanded. In exposed parts the scar of an incision is less unsightly than that following Nature's efforts. When pus deeply underlies important vessels or nerves a small incision through the skin and fascia should be made, the tissues bored through with a grooved director until pus is reached, along this instrument a pair of dressing-forceps be introduced, closed, and withdrawn partly opened, thus lacerating the structures without risk to arteries or nerves; a drainage-tube can then be inserted. This is "Hilton's method." Rarely, from loss of support, severe venous hemorrhage follows opening an abscess, or later a large vessel—vein or artery—ulcerates.

[So-called chronic or cold abscess, being really a tubercular process, will be treated of in another part of this work.

Ulcers.

As already stated, an ulcer is a solution of continuity, situated upon the skin or a mucous membrane, produced by molecular loss of substance, sometimes increased by sloughing, the result of microbic inflammation: any granulating surface left after accident or operation is also called an "ulcer."

Although ulcers may be described as belonging to one or other of certain classes, accidental conditions may cause them to change their characteristics. Ulcers are divided into those where the characteristic appearances are due to local conditions, and those resulting from specific or constitutional causes. In this section we are concerned with the first class only.

Simple Healthy or Healing Ulcer.—As every ulcer must attain this condition as it cicatrizes, the appearances of this form of ulcer must be carefully studied, all non-specific ulcers being mere variations from this type, the result of obstacles to Nature's attempt to heal by the organization of granulations and their covering over by epidermis.

The margins are smooth, shelving down to a level base, which is covered by healthy granulations moistened with a small quantity of creamy, inodorous pus. The surrounding tissues are healthy, and not inflamed. The edges of the ulcer are not tender, and merge gradually with the granulations by a bluish-white film, opaque and whiter on the skin side, bluish and translucent at the point of junction with the granulations. These appearances are due to the advancing epithelial covering, consisting of many layers resting upon slightly vascular, newly-organized granulation tissue where opaque and white, allowing the tint of the

more vascular, imperfectly-developed granulation tissue to show through the thinner layers of epithelium where bluish.

Treatment.—Protection from irritants and rest for the part are all that are usually requisite unless the surface be very extensive, when skin-grafting, preferably by Thiersch's method, may become requisite.

Fungous Ulcer.—Let anything interfere with the return circulation from a simple ulcer, as position, or excessive formation of scar-tissue in and around the margins of the ulcer, and the granulations will become congested, overgrown, ill-formed, projecting above the healthy margins, bleeding upon the slightest touch, and secreting an abundant thin, purulent, possibly blood-stained, discharge.

Treatment.—Remove the cause, by position favor the return of venous blood, employ agents which will constringe the vessels of the granulations, and give mechanical support to the circulation—*i. e.* pressure. Solutions of sulphate of copper (gr. j–x to f℥j), sulphate of zinc or nitrate of silver in the same strength, sterilized oxide-of-zinc ointment, with occasional use of the solid stick of nitrate of silver, and sometimes compression effected by a roller bandage, usually suffice.

The Œdematous Ulcer.—Employ wet dressings or prolonged poulticing, especially with a feeble venous circulation in the part, and, although the margins of a previously healing ulcer may remain fairly healthy, the granulations will become swollen, flabby, pale, semi-translucent, and friable from œdema, and will exude much watery pus.

Treatment.—Here more blood, and blood circulating at a proper rate, is demanded; hence stimulant applications, as grs. v–x of chloral to ℥j of water, resin ointment, balsam of Peru, or some astringent, and mechanical support, are indicated.

The Inflammatory Ulcer.—Let certain individuals indulge freely in alcohol, especially if previously ill-nourished and improperly fed during their drinking-bout, and a traumatism which would in others, or even in them under more favorable circumstances, produce an ordinary ulcer, often will result in a rapidly-enlarging ulcer of irregular form, having sharp-cut or ragged margins, the base formed of the red, inflamed tissues freely secreting a sero-sanguinolent discharge, which often contains shreds of tissue. If the inflammation is hyperacute, the base of the ulcer may be covered with yellowish sloughs. The circumjacent skin is inflamed and œdematous.

Inflamed Ulcer.—When a previously healthy ulcer is irritated, neglected, and dirty, especially in drinkers, inflammation may attack the granulations, which become red and swollen, and slough; the margins break down, the ulcer spreads, and the surrounding tissues present the ordinary phenomena of inflammation.

Treatment.—Removal of all local irritation, elevation of the parts, warm, moist, unirritating antiseptic lotions, as of boric acid, or, better, when feasible, the continuous warm antiseptic bath, are indicated. Drinking should be stopped, more food and of a better quality must be provided, and the eliminative organs stimulated. This combined local and general treatment will usually soon convert either the inflammatory or the inflamed ulcer into a simple one.

The Sloughing Ulcer, except when this term is applied to the worst cases of the varieties just described, is rarely seen except in con-

nection with venereal disease in those broken-down by alcohol and sexual excesses. In such patients destruction of parts progresses with great rapidity. The cellular tissue is more extensively destroyed than the skin; hence the edges of the ulcer are undermined and inverted, and of a dusky-red hue, the base being covered with gray or black sloughs. There is great pain, and severe constitutional disturbance is the rule.

Treatment.—This does not differ from that of the inflamed ulcer, except that anodynes will be required to relieve pain, and, as syphilis is often present, mercury must be used with a sparing hand or be entirely withheld. Tonics, good food, and stimulants will often be requisite.

THE PHAGEDENIC ULCER is believed to result from the multiplication of a specific micro-organism in the tissues of those broken down by intemperance, bad food, etc., and is usually of venereal (chancroidal) origin. The surrounding skin is of a dusky-red or purplish hue. The margins of the ulcer are ragged and undermined, the base is covered with bloody discharge and sloughs, and when this last condition is pronounced what is termed a "sloughing phagedena" results. The tissues melt away with astounding rapidity, the external genitals of the male or female sometimes being totally removed. Great pain and high fever are the rule.

Treatment.—As infection by a virulent organism is the cause, thorough destruction of the surface and margins of the ulcer, with some of the adjacent tissues, must be effected by strong nitric acid, bromine, or the actual cautery. In the milder forms disinfection with a 1 : 1000 corrosive-sublimate solution, followed by the free use of iodoform, may suffice. The continuous warm antiseptic bath may supersede or supplement other methods. Opium, tonics, stimulants, and good food are imperatively demanded, with improvement of the patient's hygienic surroundings if these be poor.

INDOLENT OR CHRONIC ULCER.—Let any granulating surface have its healing processes repeatedly interfered with by mechanical or other irritation, and, while the formation of epidermis is prevented, the embryonic tissue forming the margins and base will develop into dense fibrous tissue, fixing them to the subjacent fascia, periosteum, or bone. This is aided by a weak venous circulation, favoring congestion, which condition of the circulation may result either from a feeble heart, varicosity of the veins, the dependent position, or all combined. In addition, the contracting cicatricial tissue cuts off much of the arterial supply, preventing the formation of healthy granulations. Healing is also seriously interfered with by cicatricial fixation of the margins and base of the ulcer, for, as will be explained (see p. 368), much of the healing of any granulating surface depends upon diminution of its superficial area by contraction of the deeper layers of granulation tissue, which fixation of the base to the deeper structures absolutely prevents. These points must be kept in view as governing therapeutics.

Symptoms.—The lower third of the leg is the favorite position, and the poorer classes the victims. The edges are smooth, rounded, much elevated, insensitive, while the circumjacent skin is bronzed or purplish: eczema is quite common. The base has few if any granulations, and these are scattered, pale, and flabby, and covered with an oftentimes very

offensive thin, puruloid, or sanious discharge. Usually but little pain is experienced. When left untreated they last for ten, twenty, thirty, or forty years. Certain of these ulcers, if subjected to constant irritation, undergo an epitheliomatous change, and are then known as "Marjolin's ulcer."

Treatment.—This must depend upon the conditions. If access of arterial blood is prevented by the cicatricial margins, radiating incisions through these may be made, a fly blister may be applied covering base and margins, tincture of iodine may be similarly employed, or atrophy be induced by the pressure of an elastic bandage or adhesive-plaster strapping. If venous return is markedly interfered with, as is so common, rest in bed, if possible, must be employed or support afforded the veins by bandaging or an elastic stocking. In a few instances, where further contraction of the base is rendered impossible by the adherent margins, interrupted or completely encircling incisions, placed about one inch from the margins, will prove useful, the free bleeding being arrested by antiseptic packing. Again, the base and margins may be curetted, free disinfection effected by chloride of zinc in solution, peroxide of hydrogen, etc., when subsequent antiseptic dressings and the recumbent posture will often effect a cure. Where the power of the margins to reproduce epithelium is impaired, and the physical conditions are unfavorable for diminution in area by contraction, skin-grafting is indicated. Amputation is occasionally, but rarely, demanded.

When eczema of the skin surrounding any variety of ulcer is marked, the term "eczematous ulcer" has been applied. If varicose veins exist, the ulcer is often called a "varicose ulcer." Except for the fact that in the first case the condition of the skin may call for somewhat different dressings, and in the second that interference with venous return prevents that proper condition of the circulation in the parts which is essential to the formation of healthy granulations, these distinctions are worse than useless as implying some specific cause.

In certain women—usually over forty years of age—a form of ulcer is seen called the "irritable or painful." It is commonly situated above and near to the ankle—is small, superficial, and usually markedly congested. There can be no question as to the involvement of some nerve-filament standing in a causative relation. This is shown by treatment. In a few instances examining the surface carefully with the point of a probe will demonstrate some specially tender point.

Treatment.—Rest in bed, elevation of the parts, simple, non-irritating antiseptic dressings, passing a tenotome beneath the margin of the ulcer at any spot where by point-pain the involvement of a nerve-twig is demonstrable, or, where this cannot be detected, the administration of a grain of opium three or four times daily, will usually effect a cure: this latter drug is really curative, as under its use the congestion disappears, because irritation of a sensory nerve will produce congestion in the area supplied by that nerve.

Descriptions of syphilitic, gouty, tubercular, lupous, scorbutic, and carcinomatous and rodent ulcers—which last are really superficial epitheliomatous ulcers—must be sought for in the proper sections of this work.

Furuncle.

Furuncle, or boil, is a localized, deep-seated inflammation of the skin, producing one or many circumscribed, firm, acuminated, painful swellings, in which central sloughing and suppuration usually occur. Occurring in numbers and successive crops, the term "furunculosis" is applied to the condition.

Symptoms.—First, a small, reddened, ill-defined, tender point appears in the true skin. This increases in size, becomes elevated, pointed, is densely hard, very painful, and dusky red. In from a week to ten days central suppuration occurs, the little pustule ruptures, revealing a yellowish central slough, at the periphery of which pus can be expressed. In a day or two the slough separates with rather free suppuration, leaving a little crater-like cavity. The pain and suppuration now promptly subside and cicatrization occurs, leaving a purplish indurated mass for some little time. Sometimes the inflammation stops short of suppuration, a "blind boil" resulting.

Sites.—Any portion of the cutaneous surface, but preferably the face, neck, and contiguous parts, the back, axillæ, buttocks, perineum, scrotum, and extremities.

Causation.—Mental overwork, excessive bodily fatigue, irregular habits, improper food, and all causes which depress vitality seem to predispose to boils. Diabetics and anæmic patients, and those suffering from uræmia or from sepsis, are prone to them. Occasionally persons apparently in vigorous health will have frequently-recurring boils. It is alleged that the pseudo-epidemics of boils which sometimes prevail during the spring and autumn are due to atmospheric influences: this can only be true because rapid variations in temperature and atmospheric pressure produce changes in the cutaneous circulation.

Diagnosis.—The boil can hardly be confounded with anything but a carbuncle, which is larger, flattened, has many points of suppuration, is single, and is painful, but not tender.

Treatment.—Success is often not easy to attain. Removal of the cause when possible to ascertain, fresh air and moderate exercise, attention to the bowels and digestion, carefully-regulated but varied diet, tonics, quinine, arsenic and iron, sulphide of calcium, sulphite or hyposulphite of calcium, etc., have all proved useful at times.

Abortive Treatment.—When a hair is in the centre of the boil its evulsion will sometimes arrest the process. I am doubtful whether penetration of the apex with a hot needle or the use of carbolic acid is advisable, although these procedures have high authority upon their side.

Local Treatment.—As the penetration of germs, notably the *staphylococcus pyogenes aureus*, into the hair- or sweat-follicles, and thence into the epidermis, causes boils, cleansing of the parts and arrangement of the clothing, so as to prevent friction aiding penetration of micro-organisms, are important. Thus, after cleansing, a 10 per cent. salicylic-acid ointment may be gently rubbed into the skin, or ichthyol in full strength or diluted.

When suppuration has occurred or is threatening, a moist, weak germicidal dressing covered with oil-silk or rubber tissue is indicated. Anti-

sepsis and asepsis should be maintained, as more than one fatal case of pyæmia or septico-pyæmia has had its origin in a boil.

Paronychia.

Felon, or paronychia, is an infective cellulitis attacking the soft parts of the fingers, and more rarely those of the toes. This may involve the sheaths of the tendons or the periosteum. The anatomical disposition of the structures forming the pulp of the fingers will explain certain differences in the course pursued by a whitlow of a distal as compared with one of a proximal phalanx. The distal phalanges possess no separate periosteum, the vessels supplying these bones ramifying in the dense cellulo-adipose tissue forming the finger-pulps, which tissue is continuous with the skin and bone through the medium of numerous connecting fibrous bands. Hence a destructive inflammation, if deep seated, especially if it lead to sloughing of the pulp, almost necessarily leads to necrosis of the underlying portion of the phalanx. As the first and second phalanges possess a distinct periosteum, abscesses of the soft parts covering them, or a suppurative teno-synovitis, may occur without death of the bone, although this often occurs in neglected cases. Suppurative teno-synovitis in this locality may, however, extend upward, producing palmar abscess, or even, when localized, sloughing of the tendon. Paronychia is alleged sometimes to occur as an epidemic, but it more usually results from infection by pyogenic organisms of some trivial puncture, cut, or contusion, in the last event the germs gaining access to the circulation by some distant infection-atrium and becoming localized at the point of injury—*i. e.* a *locus minoris resistentiæ*.

Symptoms.—There are two distinct varieties—viz. a superficial and a deep. The superficial may attack one or several fingers in turn, and often affects the tissues around or under the nail. When slight the disease may promptly subside, but if more severe, serous or purulent collections take place beneath the epidermis, which, if removed, leaves a raw, reddened, or ulcerated derm, the cicatrix remaining for some time reddened and tender. When the inflammation runs high suppuration is free, and fungous granulations are apt to form beneath or around the nail, which after weeks, or perhaps months, exfoliates in whole or in part.

Treatment.—Rest, elevation, and moist, non-irritating antiseptic dressings are all that are requisite for the milder cases. For the more severe type antiseptic gauze or cotton poultices,[1] and prompt aseptic incision when pus forms, are indicated. Tonics and good food are required if the patient be in feeble health. If the nail mechanically maintains the irritation, it must be removed partially or entirely, the exuberant granulations be destroyed by the curette or powdered nitrate of lead, and asepsis be secured and maintained by proper dressings.

The *deep* whitlow, while it may start in the dorsum or some other surface of any phalanx if an injury be there situated, most commonly originates on the palmar surface of the finger-tip. Deep-seated inflam-

[1] By this term is meant the maintenance of warmth and moisture by covering the wetted cotton or gauze with a substance impervious to moisture, and which retains the heat, as oiled silk, waxed paper, or rubber tissue.

mations, shown by redness, tenderness, swelling, tension, and throbbing pain, manifest themselves in from a few hours to several days after the injury, with increasing fever. All the local conditions are aggravated by the dependent position. Suppuration is the rule, resolution the exception, pus usually forming early, but, owing to the density of the tissues, fluctuation is difficult to detect. Care must be exercised not to overlook the more deep-seated pus because of the occasional formation of a superficial collection of matter. Gangrene, although rare, has been observed. Abortive treatment by nitrate of silver, iodine tincture, etc. is so rarely successful that it cannot be recommended. Hot fomentations, followed by warm antiseptic poultices, may be tried for about forty-eight hours, when, if decided retrogression of the symptoms does not occur, free aseptic incision must be resorted to, especially when the last phalanx is involved, when an early cut reaching to the bone often affords the only chance of preventing necrosis. If the tissues over the first or second phalanx be involved, the early incision had better open the tendon-sheath, because probably at this time only a suppurative tenosynovitis exists, but later lateral or other incisions may become requisite, which should extend down to the bone. Spontaneous separation of the necrosed distal phalanx near the epiphyseal line will often take place, leaving a deformed but useful finger-tip. Death of a first or second phalanx usually indicates amputation, although sometimes excision of the necrosed portions may leave a fairly useful finger.

Dracontiasis.

This is due to the development of a nematode worm (Filaria or Dracunculus Medinensis, Guinea-worm) in the tissues, resulting in the formation of a subcutaneous tumor just before the exit of the worm. The larvæ of the parasite gain access to the system by the drinking-water. In Guinea, the Gold Coast, Arabia, Upper Egypt, Nubia, Abyssinia, Hindostan, and a few other localities it is endemic.

Symptoms.—Until the worm is nearly mature there are no symptoms, but a small coiled-up mass can be felt subcutaneously. In mild cases a small, circumscribed tumor forms, accompanied by itching and tension. The tumor may not form exactly where the worm was first detected. From scratching or other cause the tumor ruptures, serum escapes, and the white extremity of the worm can be seen in the cavity left. If properly treated, the worm, which soon protrudes, should be gotten rid of in from three to ten days. Some patients suffer from violent, painful inflammation along the entire worm-track, resulting in abscess with marked constitutional symptoms. Sometimes in these cases the worm perishes, softens, and thus leads to the serious accident of its breaking during extraction, which, setting free the embryos—whether the worm be dead or not—may lead to gangrene or death. This accident may sometimes end more fortunately by the discharge of the worm later on, after the formation of a new tumor. The favorite site (90 per cent.) for the extrusion of the worm is the foot, preferably the heel, but it may escape from the leg or, exceptionally, from any part of the body. While only one worm is the rule, two, or very rarely even fifty, have been noted.

The female, which produces the symptoms, has a slightly convex head,

a pointed tail, is about one-tenth of an inch in diameter, and varies in length from one to six feet, measuring upon the average from two to two and a half feet. Crowded with embryos, upon escaping from its human host, if reaching water, these penetrate a minute crustacean of the genus *Cyclops*, and there reach full larval development. When their crustacean host is swallowed the larvæ develop, conjugate, and the female migrates through the muscles, the male probably perishing and being passed with the fæces. From nine to ten months are consumed within the deep tissues in the development of the female before she appears superficially.

Diagnosis.—This can only be made by detecting the worm by the touch and noting its change of position.

Prognosis.—Unless attended by severe inflammation from the start, or the worm is broken during extraction, recovery readily occurs.

Treatment.—Antiseptic poulticing will facilitate opening, when the worm must be gently drawn out, ceasing the effort if any resistance is felt: wind what has been withdrawn around a small stick, which should be given one or more turns each day until the worm is extracted, scrupulously avoiding breaking it. Non-irritating antiseptic dressings may be applied. Asafœtida in large doses internally is said to kill the worm. The violent inflammation so commonly following rupture of the worm must be treated upon general surgical principles. If gangrene occur, amputation may become necessary.

Madura Foot (Mycetoma; Fungous Disease of India).

Endemic in certain portions of India and occurring only in natives, this disease most frequently attacks males, especially field-workers and those who pursue their avocations with bare feet. Although found at any age, it is rare below puberty. Some trivial injury, as a prick or an abrasion, is alleged as the exciting cause, but often neither predisposing nor exciting cause can be detected. From the difference in color two forms have been described—viz. the pale and the black, the latter being the more common.

Pathology.—Vandyke Carter's original explanation no longer holds good—viz. that the disease results from the fungus *Chionyphe Carteri*—but his later suggestion, made in 1886, has received confirmatory proof by the recent work of Kauthack, who has shown Madura foot to be a variety of actinomycosis, his conclusions being as follows: "That (1) the fish-roe masses are undoubtedly a form of actinomyces; (2) the black masses in their most perfect shape are also undoubtedly of this nature, but in a state of degeneration; (3) a degenerated form of the yellow variety is occasionally found, in appearance not wholly unlike these black masses, so that the relation between all these forms seems to be fully established."[1] Fibroid and fatty changes so alter the tissues that it is often difficult to distinguish them apart, all being changed into an opaque, homogeneous, gelatinous mass, many of the bones being replaced by fibrous tissue. The muscular tissue is the least altered, while the adipose tissue is much increased and often contains pigment-granules. The sinuses which riddle the foot in all directions are peculiar in that, while

[1] *Journal of Pathology and Bacteriology*, vol. i. p. 140, et seq.

piercing the bones "as if they had been drilled," their osseous walls are often unaffected with the degeneration, and that they open into single or multiple rounded cavities containing numerous granules, which latter are likewise scattered over the sinus-walls or are free in their lumina. The lighter granules consist of a central close mycelial network "and a peri-peripheral fringe of more transparent, more or less glassy, rays." The black granules are chiefly formed of the inorganic constituents of the tissues, pigment, and the more or less altered fungus.

Symptoms.—The part attacked is nearly always the foot or leg, next in frequency the hand or arm, very rarely the shoulder or scrotum. The onset varies. Thus, a toe or finger, or the foot itself, may be attacked, very little swelling, redness, or circumscribed induration being noticeable. Again, either a superficial or deep papule, pustule, or tubercle may appear, moderately tender, which on rupturing discharges pus, but later the characteristic granules. Occasionally a subcutaneous mottling exists for some time before the skin gives way. Slowly, accompanied by severe pains, the foot becomes enormously swollen, distorted, and useless; the arch of the foot gives way from destruction of the bones, so that even over-extension of the toes takes place. Scattered over the skin are small elevations, whose centres are the orifices of the sinuses leading into the cavities before mentioned. These latter may be near the surface or deeply seated, and sometimes involve the lower ends of the tibia and fibula as well as the bones of the foot. The discharge is sero-purulent, and contains the characteristic white, yellow, black, or very rarely pink or red granules resembling fish-roe. The granules also lie scattered on the surface around the orifices of the sinuses. It may take six to twelve years completely to disorganize the member, but the disease tends to a fatal termination.

Diagnosis.—Commencing as a tubercle or pustule, until either ruptures it might be difficult to decide between mycetoma and the Guinea-worm disease, but the absence of the worm and the roe-like material in the discharge would settle its nature. In advanced cases the fact of an extremity being concerned, the marked swelling, the numerous sinuses, and the characteristic granular discharge should suffice.

Prognosis.—If left to nature, complete disorganization of the member will result.

Treatment.—When superficial, early free curetting has proved effectual. If only a finger or toe is involved, its prompt removal will usually suffice. In more advanced cases amputation is the sole resort, and, as the leg-bones may have undergone change much higher than external appearances would indicate, the bones must be removed well above any suspicious point.

Pernio, or Chilblain.

This is produced by the sudden application of cold to any exposed portion of the body where the circulation is impaired. The vascular condition may be due to a weak heart or to the distance of the part from the centre of the circulation, as in the case of the ears or toes. In the latter instance the compression of the foot-gear also favors anæmia. Sudden approach to the fire after exposure is a common cause, owing to the change of temperature causing intense congestion from vasomotor

paresis. Children whose power of generating heat is feeble, and those adults who resemble them in this particular, are most liable to chilblain.

Symptoms.—The mild form amounts only to a moderate redness of the skin and some swelling, with heat and itching of the parts, which disappear spontaneously. Another variety is evidenced by marked swelling and redness, the latter often assuming a purplish hue due to venous congestion. The heat, itching, and tingling pain are very marked, especially when the parts become warm after the slightest chilling. This form usually does well with proper treatment. In its worst form pernio closely resembles frost-bite from the severity of the inflammation, blebs forming which on rupturing leave indolent ulcers, sometimes covered with sloughs, "yielding a thin ichorous or sanious discharge."

Treatment.—Prophylaxis is important, and consists in woollen coverings for the feet and appropriate ones for the hands and exposed parts. Local stimulation of the circulation by dry frictions or with alcohol, spirits of camphor, or soap liniment is useful as a prophylactic. Entering a warm room or coming close to a fire, even after exposure to slight cold, must be avoided. When the milder form is threatened gentle friction with snow or ice-water until reaction begins to be established, in a cold or only moderately warm room, is to be recommended, followed by an alcohol dressing, or even tincture of iodine when no blisters have formed. Where persistent congestion with tendency to swelling, attacks of itching, etc., repeatedly occur, the constant current and local applications[1] to produce contraction of the paretic vessels, coupled with tonics and measures calculated to invigorate the circulation, will usually give relief. If ulceration or sloughing occur, it must be treated upon general principles.

FROST-BITE.

This term includes the more serious effects resulting locally from the abstraction of heat—miscalled "application of cold." Exposure to low temperatures causes destruction of parts in two ways—*i. e.* (1) directly, by freezing the tissues so thoroughly and for such a time that, even when most carefully treated, after thawing they are found to be dead; and (2) more commonly indirectly, gangrene resulting partly from the lowered vitality, but chiefly from the subsequent inflammation, causing strangulation and death of the enfeebled tissues by the exudates; in other words, so-called "inflammatory gangrene" determines the sloughing or sphacelus. The effect of cold being to promote adhesion of the leucocytes, capillary thromboses are readily formed, favoring and often determining gangrene.

Symptoms.—First, numbness with loss of power is felt, usually in peripheral parts, as the nose, ears, fingers, or toes; then tingling and a sensation of weight are noticed. Inspection now shows that the parts are bleached white and icy cold to the touch, all sensation being lost. If hopelessly frozen, discoloration and swelling follow the primary blanching; the parts next shrivel and contract; a line of separation follows; putrefactive changes ensue; and the nose, ears, feet, or hands may

[1] Camphorated soap liniment, turpentine with copaiba, lead-water, alum in solution, with numerous similar substances, have been all vaunted, but careful prophylaxis is requisite to render any treatment of avail.

be spontaneously amputated. When too rapid thawing precipitates gangrene, or judicious efforts fail to maintain the vitality of the part, the primary swelling and abnormal sensibility are followed by intense inflammatory phenomena; blebs form; the pain ceases; the skin becomes mottled and discolored; and finally the parts manifest all the phenomena of moist gangrene.

Treatment.—This must secure a most gradual restoration of circulation, and with this the power of calorification. Sudden increase of temperature will induce such a paretic condition of the vasomotor system as will produce stasis, coagulation-necrosis, and gangrene. Commencing by frictions with snow, then immersion of the part in water, all treatment being conducted in a cold apartment, the temperature of the applications and of the room must be gradually raised until the somatic and local temperatures have nearly attained the normal, when applications which tend to stimulate to action the paretic local vasomotor apparatus are indicated, such as diluted alcohol or diluted spirits of camphor. Elevation of the parts, which should be swathed in raw cotton, will tend to relieve the venous stasis by favoring the return of blood. Warm stimulating drinks, as hot coffee, aromatic spirits of ammonia, or whiskey diluted with hot water, are now indicated. Should inflammation run high, threatening gangrene, antiseptic irrigations may be employed, and in any event asepsis and antisepsis must be maintained throughout. If gangrene results despite all efforts, the constitutional and local treatment advised on pages 358, 359 should be adopted.

Gangrene.

Sphacelus, gangrene, mortification,[1] and sloughing are all terms which indicate the death of tissues in greater or smaller masses. This condition is always the result of two factors combined in varying proportions—viz. an insufficient supply of nourishment to the cells, producing a lowering of tissue-cell vitality, and their mechanical destruction. The deprivation of pabulum may be induced in many ways. Thus, the main artery of the limb may be occluded suddenly or gradually; the main veins may become thrombosed, preventing the return of blood, or both conditions may obtain: again, inflammation may lead to such free exudation that the blood-vessels, plasma-channels, and even the cells themselves, may be so compressed as to be unable to maintain their vitality. If to this last condition be added death of some of the cells by mechanical injury, or their lowered vitality brought about by other predisposing conditions, mortification still more readily occurs. In certain injuries of the cerebro-spinal axis or of the peripheral nerves, local gangrene often supervenes, precipitated by pressure, but probably predisposed to by interference with vasomotor equilibrium.

Two types of gangrene exist—the moist and the dry—the presence or absence of fluids in the tissues when gangrene occurs determining to which class the case belongs, the difference being purely a physical one.

Dry Gangrene.—This is usually caused by a gradual diminution

[1] Necrosis is a term which should be restricted to death of bone or to gangrene of the viscera where the absence of putrefactive organisms admits of absorption of the dead tissues, a scar remaining.

of the arterial supply, the venous blood having free egress. Occasionally dry gangrene follows embolism. Because atheroma leads to such arterial changes as interfere with the vascular supply, and as this disease is more common in the old, in whom the feeble heart also predisposes to malnutrition of the peripheral tissues, dry gangrene is often called "senile gangrene;" but with the same physical conditions, notably in chronic ergotism, typical gangrene of the feet, hands, nose, and tips of the ears may occur in the young. Vasomotor spasm, a feeble heart, and ill-nourished tissues all result from living for long periods on spurred rye.

Symptoms.—Coldness and numbness of the feet, with cramps in them or in the calf-muscles, are frequent prodromes. After bruising a toe, trimming a corn too closely, or from the friction of the boot, congestion and inflammation occur. The blush deepens, becomes purplish; the part is insensitive and cold, but oftentimes severe pain is experienced in the neighboring tissues. The dead parts dry, shrivel, and blacken, emitting the odor of decomposition. An inflammatory line of demarcation marks the boundary between the dead and living tissues, shifting upward as the disease progresses until it is arrested, when septic ulceration soon establishes a line of separation. The gangrene may be restricted to one toe or may gradually involve the whole foot and leg, but usually stops just below the knee—*i. e.* about the bifurcation of the popliteal artery. Little if any fever may attend upon destruction of one or two toes, but where much tissue dies septic fever becomes more or less pronounced. Pain varies from a mere burning sensation to such agony as to require the constant use of morphine.

Moist Gangrene.—Sudden obstruction to the main arterial current, as by embolism or ligature, interference with the return of the venous blood, and cutting off of the ultimate blood-supply to the tissues by the pressure of inflammatory exudates are the usual causes. Because moist gangrene so often follows traumatism it has been sometimes called "traumatic gangrene." The disease may occur either as a localized traumatic or a spreading traumatic gangrene.

Localized Traumatic Gangrene.—The injury unquestionably physically devitalizes portions of the tissues, but the chief destruction results from the products of the septic inflammation so compressing the vascular supply (capillary and arterial) to the tissue-cells that they die: doubtless ferments and ptomaïnes also play a part. The damaged tissues perish with some of the surrounding parts from the inflammation, but the process does not extend indefinitely.

Symptoms.—The burning pain often preceding mortification entirely ceases; the skin is cold, pale, insensitive, then becomes mottled green or red, and finally livid. Blebs form containing brownish serum. When the blebs are ruptured they leave a dermis resembling moist smoked beef; moreover, before rupture they can be slipped around over the dead derm, because the devitalized epithelium readily separates, thus being distinguishable from the blisters forming after inflammation. The surfaces of the wound become pulpy, yellowish or grayish, and exude a profuse offensive discharge, and the dead part undergoes putrefactive changes. The dead tissues contrast sharply with the living, intensely reddened tissues, separation occurring from septic ulcerative inflammation unless the patient dies from sapræmia, which is unusual, and recovery

ensues. Hemorrhage is not common, because softening of the thrombi which form in the vessels by the action of the products of germ-growth rarely occurs. The prognosis is better when the original injury has produced either an extensive wound or many wounds of the soft parts, which allow vent for the poison-laden discharges.

Spreading Traumatic Gangrene.—This results from specific infection of tissues whose vitality has been lowered by severe traumatism, especially if the main vessels are destroyed. Where the vessels are intact the rapidly-spreading infective inflammation destroys the tissues, partly by strangulation of their minute blood-supply, but chiefly by the effects of the ptomaïnes, peptonizing ferments, etc. which are generated and confined under pressure. Hence severe crushes with but trivial division of the soft parts are most dangerous. The infection is often a mixed one, but sometimes one only of the pathogenic germs is present. The cellular tissue is that which is chiefly attacked; hence the disease is more extensive than external appearances would indicate.

Symptoms.—The limb becomes tense and brawny, the skin of a dull reddish brown, variegated with streaks and spots of green or black. Emphysematous crackling can often be felt, which extends somewhat above the point of apparent skin-involvement, and usually higher upon the inner side of the limb. The gangrene extends with lightning speed, sometimes in less than forty-eight hours involving a whole lower limb with half of the abdomen and trunk. So soon as the local condition is fairly started, owing to the absorption of enormous doses of ptomaïnes and toxines by the lymphatics of the cellular tissue, which are unblocked by any exudate upon the proximal side, marked constitutional symptoms of sapræmia develop, which soon terminates fatally unless art intervenes.

Constitutional Symptoms.—If the process be extensive or involves an important organ, the heart acts feebly, the pulse is quick, compressible, and small, the tongue dry, brown, and covered with sordes which extends around the teeth and upon the lips; in fact, a typhoid state exists.

Treatment.—If possible, remove the determining cause, which can often be done by strict antisepsis after injuries, especially in the aged, and, in threatened gangrene of a crushed limb, by incisions which will give exit to septic discharges and relieve strangulation of tissue. If obstruction of the main vessel has occurred, favor the establishment of the collateral circulation by moderate elevation of the limb, warmth, and cardiac stimulants. Thorough disinfection of gangrenous parts, followed by dry antiseptic dressing, such as iodoform or boric acid combined with powdered charcoal, often prevents septic infection. Inflammatory products must be evacuated by incisions carried, when possible, through the dead tissues. When the process tends to self-limitation in senile gangrene, delay is advisable, removing the dead tissues from time to time; secondary amputation may be done later if the stump does not heal. When senile gangrene spreads, although an amputation below the knee may succeed, removal of the limb at the lower third of the thigh is better, because the blood-supply to the flaps comes from the profunda femoris.

In embolic gangrene it is best to delay until a line of demarcation forms, otherwise an unnecessary sacrifice of parts may result.

For localized gangrene—*i. e.* sloughing of the skin and subjacent

tissues—nothing is requisite, except incisions through or partial removal of the dead tissue to evacuate pus, until the line of separation forms. Gangrene caused by crushing of a limb demands immediate amputation if the process is rapidly extending. If, however, it is localized, the general condition of the patient must decide what must be done—*i. e.* if septic absorption is producing marked constitutional effects and the patient can stand the shock, amputate; if not, strive to improve the general condition, endeavoring to prevent further absorption of, and to eliminate, all ptomaïnes which have been already taken up. The only measure offering any prospect of success in spreading traumatic gangrene is prompt amputation far above the apparent external limits of the disease. Sometimes, as at the shoulder-joint, flaps may be successfully fashioned out of infiltrated, œdematous tissue. The flaps must be long, and if there be doubt if all infected tissue has been removed, primary suturing had better be avoided, antiseptic irrigation employed, and secondary suturing resorted to later. Alcohol and cardiac stimulants, with quinine and opium to secure sleep, must be given. Large quantities of easily-assimilable food should be provided. Care must be taken to see that the kidneys and bowels eliminate properly.

Hospital Gangrene is an infective microbic disease which usually attacks an open wound, but has followed subcutaneous injuries. The disease is hardly known now, owing to the avoidance of overcrowding of patients and to antisepsis, the virus probably being a special micrococcus which may reach the wound through the medium of the air, the nurse's or surgeon's hands, instruments—above all, sponges. The microbes, in both masses and chains, are present in the slough and the surrounding tissues, but not in the blood. Three distinct forms have been described—viz. the diphtheritic, the ulcerative, and the pulpy. The first variety—thought by some to be a mild form of hospital gangrene, but by others to result from a different and specific micrococcus—produces a coagulation-necrosis of the granulations, the wound-surface being covered with a yellowish or grayish-white, tenacious pseudo-membrane; the discharge is at first scanty, but later becomes more abundant and watery. This form is but slightly contagious, and only produces systemic results by ptomaïne absorption. When the sloughs separate a deep excavation is left, but during the whole process there is little inflammation in the surrounding tissues. The ulcerating variety is characterized by a rapidly-spreading, rather superficial ulcer, covered by unhealthy grayish granulations, with inflamed, reddened, sharp-cut edges: the discharge is free and excessively offensive. The pulpy form is often epidemic, and when attacking an open wound causes great swelling of the granulations. Pultaceous, ash-gray, adherent sloughs soon form, extending rapidly in depth and extent, with a profuse, thin, greenish or sanious offensive discharge. The surrounding tissues are dusky-red, swollen, œdematous, the margins of the ulcerated surface being sharp-cut, elevated, and excessively tender. The main vessels may become eroded, producing hemorrhage, and even large joints may be laid open. Profound constitutional symptoms, assuming a typhoid character, due to ptomaïne absorption, set in early, sometimes producing death in a few hours.

Treatment.—Prompt isolation must be effected. Where numbers of patients, as soldiers, are attacked, tents or huts are preferable, even

in cold weather, to crowded wards. The patient's strength must be sustained by food, stimulants, quinine, strychnia, and digitalis, and opium given to obtain sleep. The emunctories—by which the absorbed ptomaïnes may be eliminated—should be stimulated. Locally, in the diphtheritic form, efficient disinfection, followed by the free use of iodoform, will often suffice, but in the more severe varieties the patient must be anæsthetized, all sloughs cleared away, and what still adheres of them, with the surrounding infected area, must be thoroughly destroyed with bromine, nitric acid, or the thermo-cautery. After this, free dusting with iodoform and the careful use of wet antiseptic dressings will bring about recovery if the systemic infection be not too great, *provided all infected tissue has been destroyed;* if recrudescence of the local symptoms occurs, a repetition of the caustic treatment is indicated.

Bed-sores, or Decubitus.—This is a moist gangrene, produced by pressure mechanically interfering with the access of blood to the tissues of patients lying for a considerable time in one position. The weak heart and tissues of such individuals predispose to gangrene, bed-sores occurring most frequently during acute or chronic exhausting ailments or in parts deprived of nerve-influence, as after fracture of the spine. When the slough has separated the ulceration sometimes extends widely and deeply, and may end in death by pyæmia, hectic, or exhausting discharges. The most common sites for bed-sores are over the coccyx and sacrum, the great trochanters, the shoulder-blades, malleoli, and back of the heels.

Treatment.—Bed-sores can usually be prevented by frequent bathing of parts subjected to pressure, covering the same with soap plaster spread upon wash-leather, removing pressure by padded or air rings, pillows, etc., and frequent change of position. Once formed, removal of pressure as far as possible, disinfection, and dry dressings must be tried. After separation of the sloughs the resultant ulcer must be treated as recommended elsewhere.

White Gangrene.—The etiology is obscure, and it is said to be due to some general, not local, cause. It is a recurrent disease, and appears during early adult life in those who are feeble and ill-fed. It is probably due to some peculiar localized vasomotor condition producing a nearly perfect anæmia of the dead parts.

Symptoms.—Although any part may be the seat of the disease, the extremities are the parts usually attacked, and by preference the lower ones. Pain, following the course of the main nerves if a limb is attacked, precedes each attack, lasting for weeks or even months. Irregular menstruation and various nervous symptoms are observed in females. Locally, a circumscribed spot on the limb, usually circular in outline, or a toe, becomes dull white; the skin soon dries and shrivels; by a septic inflammation a red line of separation forms, and the slough comes away, leaving a granulating surface. When only the skin is involved, the disease is comparatively trivial, but when all the soft parts down to the bones are destroyed, it is a serious, and sometimes a fatal, affection.

Treatment.—This does not differ from what is recommended for the other forms, but the constant current is suggested, so as to modify the vasomotor condition of the parts.

Glycosuria.—The relation borne by glycosuria to gangrene may be briefly stated thus: While patients whose urine contains sugar are more liable to suffer from gangrene which pursues a rapid course, because the tissues of diabetics are weak and probably afford favorable pabulum for the growth of germs, the mere presence of sugar does not cause the disease. Again, diabetics very frequently have arterio-sclerosis[1] and a variety of peripheral neuritis closely resembling that produced by alcohol. The neuritis[2] attacks by preference the nerves of the lower extremities, giving rise to perforating ulcer, the knee-jerks being temporarily or permanently abolished, but the Argyll-Robertson pupil has not been observed. Gangrene occurs in patients with sugar in the urine who belong to three main classes, as pointed out by Godlee—viz. (1) simple diabetics; (2) gouty persons with sugar in the urine; and (3) diabetics who are also gouty. The determining causes are inflammation (perhaps very slight), coinciding with either arterio-sclerosis or neuritis, the first variety usually being painful and spreading rapidly, the neurotic form being slower and comparatively painless.

Treatment.—All operative interference has been opposed until recently, but numerous observers have shown that when painful and rapidly spreading—*i. e.* when arterio-sclerosis is present with plugging of the vessels—a prompt knee or thigh amputation often saves life, and the sugar sinks to a minimum after healing, when during the gangrenous inflammation neither medicine nor diet availed. The chief causes of failure are a too low amputation through the area whose main vessels are thrombosed, including infected tissues in the flaps, after infection, and late operation, especially in those in whom the urine has become albuminous. In the neurotic form, where one or two toes are involved, spontaneous separation and recovery sometimes occur, and in this variety, and in that starting from a perforating ulcer, delay with removal of the dead parts and antisepsis is permissible—nay, often advisable. Dietetic and medicinal treatment after operation is requisite, often converting the more acute into the chronic form of diabetes, and in the chronic form, where of course the prognosis is better, life may be prolonged for many years.[3]

Symmetrical Gangrene, or Raynaud's Disease, is a rare affection, believed to arise from a condition of the vasomotor apparatus in which it reacts abnormally to cold or other irritants, producing by reflex action persistent vaso-constrictor spasm. Although attacking any peripheral parts exposed to cold, the tip of the nose, an ear, the cheeks, and the tips of the fingers and toes are the parts usually involved. Children or young adults are those usually attacked.

Symptoms.—Usually a varying period, marked by intermitting attacks of pallor, coldness, and numbness of the parts, is noted—*i. e. local syncope;* in many cases the next symptom is a bluish, congested appearance presented by the parts (*local asphyxia*), which is accompa-

[1] Israel found this in 13 of 20 diabetics.

[2] Ziemssen first suggested this causal relation of sugar and this form of neuritis in 1885, while Leyden in 1888, and later writers, have classified the varieties.

[3] The reader is referred to vol. lxxv. pp. 395–403, and vol. lxxvi., of the *Medico-Chirurgical Trans.*, p. 37 et seq., for two admirable articles on the subject of diabetic gangrene. An excellent bibliography will be found, and a résumé of the whole subject to date.

nied by burning pain; finally, gangrene actually sets in, usually assuming the dry form, but at times it is preceded by the formation of blebs, when of course moist gangrene or sloughing results. Hæmaturia is a frequently associated condition.

Prognosis.—As yet no deaths have resulted.

Treatment.—Protection of the parts from cold and the application of the constant descending current have been alleged to have proven effectual in warding off gangrene when only the stage of local asphyxia has been reached.

Burns and Scalds.

Burns result from direct flame, radiated heat, or heated substances; scalds, from hot fluids—*i. e.* moist heat. The former are apt to be deeper and more circumscribed, the latter more superficial and covering a wider area, because fluid flows over surfaces or is diffused by saturation of the clothing. Burns and scalds are clinically so nearly alike that they will be considered together.

The sun's rays, direct flame, heated water, coffee, oil, or other dense fluids, molten metal, concentrated acids and alkalies, are the agents producing these injuries. The effects depend, first, upon the actual temperature, and second, upon the period of application. Thus, instantaneous contact of even molten metal splashed so as to touch the skin produces vesication, while boiling water or oil kept in contact for a longer period will destroy the skin or even deeper tissues. While severe scalds from water may leave the cutaneous hairs, thus enabling us to differentiate a scald from a burn, the hairs may be destroyed by *dense* liquids, which can be raised to a much higher temperature. Concentrated acids and alkalies do not vesicate, inflammation promptly supervening with marked cellulitis, the surface being covered with a grayish exudate. On the face these injuries give rise to rapid erysipeloid swelling. Nitric acid stains the parts yellow, sulphuric acid reddish, and carbolic acid, after the white stage is past, of a peculiar coppery color.

Constitutional Effects of Burns.—Shock is pronounced in all severe burns, varying according to position. Thus even superficial burns of the chest, abdomen, head, or neck, if covering much surface, will produce more shock than deep destruction of a foot or hand: shock is often fatal. A severe chill is not uncommon after extensive burns, and but little pain may be complained of; coma sometimes sets in, death resulting from cerebral and other visceral congestions. If reaction takes place, sthenic fever is pronounced in from twenty-four to forty-eight hours, inflammation occurring around the burned spots. The congestion of the viscera which occurs during the stage of shock may run on to inflammation, and perforating duodenal ulcer may now commence. During and after separation of the sloughs death may result from suppuration, exhaustion, and hectic, aided perhaps by secondary hemorrhage.

Capillary embolism of the kidneys and other organs by the débris of altered and destroyed red corpuscles is supposed to explain certain cases of sudden death after burns, because large numbers of these cells have been shown by Ponfick to be destroyed immediately after severe burns inflicted on animals.

Complications of Burns and Scalds.—Scalds of the mouth and pharynx, chiefly incurred by children attempting to drink boiling water from the spouts of tea-kettles, and burns where superheated air is inspired, often cause œdema of the glottis, commonly a fatal condition even after tracheotomy or intubation. Gastro-intestinal irritation or inflammation is frequent, varying from a little nausea and vomiting, with an occasional loose movement, to constant rejection of food and frequent stools containing blood. In the latter condition duodenal ulcer is probable if sudden collapse occurs, especially if pain and tenderness have been noted in the epigastrium.

The pathology of gastric or duodenal ulcer under such circumstances is uncertain. These lesions probably result from local arrest of the circulation, brought about by thrombosis of the small vessels initiated by accumulation of the remains of disintegrated cells during the congestion occurring in shock, and the subsequent digestion of these necrotic areas by the digestive juices. According to Ziemssen, both gastric and duodenal ulcers have sharp-cut edges, which are indurated when the process is old, and are of a funnel-shape because more mucous membrane is gone than muscular substance, and less muscular than serous tissue if actual perforation has occurred, as occasionally happens.

Albumin is always present in the urine, except in injuries of the first degree where no rise of temperature occurs, the quantity seemingly being in proportion to this rise. Hæmoglobinuria is also common.

Classification.—The classification adopted by Morton is better, because less complex, than that of Dupuytren—viz. First degree: Hyperæmia, erythema, or inflammation of the skin without vesication; no scar results. Second degree: Inflammation of skin with vesication; no scar, but staining possibly from pigmentation follows. Third degree: in addition to all seen in the other degrees, destruction of the skin and subjacent tissues to varying degrees up to complete charring of the parts; much of the subsequent scarring and deformity results not from the primary injury, but from the consecutive sloughing or gangrene.

Symptoms.—BURNS OF FIRST DEGREE.—*Local Symptoms.*—The diffused redness disappears upon pressure, instantly to return. Swelling sometimes occurs, and the pain is burning or smarting. Lasting from a few hours to some days, these symptoms decline, epidermic desquamation then occurring.

Constitutional Symptoms.—While unusual, slight fever may develop, but in certain patients and from the extent of surface involved shock is pronounced, and even death may result. This almost certainly occurs if two-thirds of the skin is merely reddened. Cerebral, pulmonary, gastro-intestinal, and even vesical complications have been reported.

BURNS OF THE SECOND DEGREE.—*Local Symptoms.*—The inflammation goes on to separation of the epidermis from the derm by serum, forming vesicles or bullæ. If these form very rapidly, the epidermis may rupture, leaving collapsed, wrinkled, whitish pellicles, through which here and there can be seen the inflamed hypersensitive derm. If suppuration and ulceration do not occur—*i. e.* if infection is prevented—the epidermis is re-formed in a week or two, possibly leaving some pigmentation.

Constitutional Symptoms.—When involving a limited area only slight effects result, but when covering much surface the shock is severe, often promptly terminating in death with delirium and coma or symptoms of congestion of the lungs or other viscera. If reaction takes place, visceral congestions may terminate in visceral inflammations. Still later, albuminuria is common and intestinal ulceration occasional.

BURNS OF THE THIRD DEGREE.—*Local Symptoms.*—It is impossible immediately to determine by inspection how deeply the tissues are destroyed, as the surface indications are very similar "when the muscles or the deeper parts, even the bones, have been involved." Moreover, much of the subsequent destruction results from the sloughing and gangrene from septic inflammation. It is therefore useless to attempt to describe the endless differences in appearance presented by this class of burns. Sometimes fingers, toes, parts of hands, or feet may be burnt off. Molten metal poured into a puddler's boot will produce such an injury.

Constitutional Symptoms.—If reaction takes place, death from cerebral coma, caused by serous effusion, sometimes occurs. Congestions followed by inflammations of lungs, kidneys, or intestines may result fatally. Pyæmia, septicæmia, exhaustion aggravated by hemorrhages, tetanus, one or all, may cause death during the process of separation of the sloughs or subsequently. High temperature with renal trouble is common.

Prognosis of Burns.—This depends on many circumstances. Aseptic and antiseptic methods have so diminished the death-rate that the old statements as to the mortality of an injury of given extent and depth must be modified. Young children and those suffering from shock may be severely burnt or scalded by comparatively low temperatures, the injury at first appearing trivial, but soon extending to the deeper parts. Old drunkards, those with renal or hepatic disease, often succumb when those with healthy organs would recover. Laryngitis with œdema glottidis places patients in great peril. Delirium due to changes in the blood-supply of the cerebral cortex has been observed: this is explainable by the reflex effects produced upon the vasomotor system or by thrombosis produced by disintegrated red corpuscles.

Treatment.—First relieve pain and treat the shock. Where mere erythema exists, unless much surface is involved, only local treatment is requisite, dressings such as will exclude the air or will neutralise the acidity of the secretions being indicated. Oil, fresh lard, or cosmoline, previously sterilized by heating, best fulfil the first indication, while a paste of bicarbonate of soda made with sterilized water will meet the second. In burns of the second and third degree, if much surface is damaged, two courses are open—viz. a preliminary thorough disinfection with a weak mercuric-bichloride solution, followed by a moist dressing impregnated with some non-poisonous germicide, as borosalicylic solution or hydronaphthol, the whole covered with oiled silk; or, after the preliminary cleansing, all injured parts must be carefully covered with protective, *outside* which a wet sublimate or other poisonous germicide may be safely applied, with abundance of cotton externally. When such a dressing requires changing—which should only be done at as long intervals as possible—any cleansing needed can be effected by

sterilized water or some non-poisonous, non-irritating antiseptic solution. Irritating and readily-absorbed poisonous substances, like carbolic acid and corrosive sublimate, should be eschewed if possible, and *never* kept in contact with large surfaces, lest constitutional effects result. The constant warm sterilized-water bath, when feasible, or antiseptic irrigation, is useful where much sloughing results, but is only applicable to extremities, and is not easy to manage effectively: moreover, absorption of poisonous substances readily occurs during irrigation or baths, and must be carefully guarded against.

After separation of the sloughs healing of the granulating surface must be promoted, upon general principles. The granulations are apt to become either congested and fungous, bleeding readily, or œdematous. For the former condition soothing and slightly astringent applications, such as sterilized zinc-oxide ointment, must be used; for the latter moist dressings should be, as a rule, avoided: astringent and stimulating dressings, as resin cerate, applications of solution of zinc sulphate (grs. j–x to f℥j) or of copper sulphate in similar proportions with each dressing, with the occasional use of solid nitrate of silver to the margins, are about the best. Chloral hydrate, grs. x to f℥j aquæ, applied by means of lint covered with oiled silk, will often act admirably, but is apt to produce a congested, fungous state of the granulations if employed too long. It must be remembered that unless the whole thickness of the skin be destroyed the epithelium around the hair- and sebaceous follicles will proliferate, thus accounting for the epidermic islets appearing in the midst of the granulating surfaces left after burns. These centres of cicatrization must be carefully conserved. Skin-grafting, preferably by Thiersch's method, and plastic operations, are often requisite to secure healing. The deformities resulting from cicatricial contraction may to a certain extent be obviated by position, splints, etc. employed during the healing process, but when much skin and fascia have been destroyed some plastic procedure will become requisite. Such operations are inadvisable until all tendency to contraction has ceased—*i. e.* usually in from six to nine months—unless the lower jaw is becoming curved downward by the traction in the very young, when perhaps some operative interference may be warranted earlier.

Sunburn.—While usually only annoying, causing much burning pain, when a great extent of surface, as two-thirds, is involved, death has resulted from the severe dermatitis and subsequent gangrene. Extensive vesication is common. Erysipelas is closely simulated at times when the face and eyelids are involved, but there is no febrile disturbance.[1]

Treatment.—It is that of a burn of the first degree.

Brush Burn.—This variety of contused wound is caused by rapid friction, as that produced by the revolving leather belts of machinery or the dragging of a patient over the roadbed by a train of cars or by a runaway team. This painful condition may vary from a superficial abrasion to complete destruction of the skin and underlying tissues. It is rarely extensive enough to be dangerous.

[1] See vol ii. p. 224, *Internat. Ency. of Surg.* Longstreth here reports one case where the muscles and synovial tendinous sheaths of the forearm and wrist became secondarily involved.

Treatment.—This is identical with that of a contused wound which sloughs.

LIGHTNING-STROKE.—While it is true that the passage of a powerful current of aërial electricity through the human frame usually results in death, this is not invariable. What is commonly called "struck by lightning" means that air-induced electrical shock occurs in the individual when some contiguous object, as a tree or another person, receives the direct electrical discharge.

Symptoms.—In non-fatal cases the phenomena of shock are pronounced, unconsciousness or coma lasting from a few hours to days. Impairment of one or more of the special senses is common, with paresis or paralysis of both upper and lower extremities. Localized anæsthesia is quite usual. These pareses or paralyses are usually transitory, except perhaps that of vision. Locally, burns of varying depths are not uncommon, while simple or compound and comminuted fractures, and even partial or complete avulsions of extremities, have been reported. A peculiar arborescent series of tracks, characterized by slightly œdematous, raised, bright-red lines, often diverge from the point where the current entered. Where death is delayed it results from shock, cerebral effusions—hemorrhagic or otherwise—or hemorrhages into some of the great cavities, with perhaps rupture of some of the contained organs, or the severe fractures already mentioned.

Treatment.—This must be conducted upon the general principles governing the treatment of shock, burns, or paralysis of any nerve or nerves.

WOUNDS.

A wound is a solution of continuity suddenly effected by anything which cuts or tears. When this is effected without division of the skin, the term "subcutaneous" is employed, the injury giving rise to little or no constitutional symptoms, and healing taking place by simple adhesive inflammation.

Wounds are usually classed, according to their causation, as incised, when resulting from a sharp-edged object; contused, when produced by more diffused force, which divides the tissues, leaving the wound-edges bruised, as from the blow of a bludgeon; lacerated, when irregularly torn, as by the bite of a wild beast, entanglement in machinery, etc.; punctured, when the depth much exceeds the superficial area, as bayonet, knife, and sword wounds.

INCISED WOUNDS.—Because the injury cleanly divides the tissues, not dragging on or tearing contiguous sensitive parts, the pain is apt to be less in this variety of wound. The bleeding varies, but is much freer than in lacerated or contused wounds. Wounds of the face bleed very freely even if no considerable vessel be divided, the same being true of the scalp; but in this latter situation the hemorrhage occurs because the density of the scalp-structures interferes with the contraction and retraction of the vessels.

Retraction of the edges of incised wounds always occurs, dependent upon the position and subjacent structures. This point it is important to remember, because if incisions are properly planned few sutures will be requisite, and these will be efficient; thus skin and fascial wounds made

transversely to the course of underlying muscular fibres will gape widely, but if made parallel to the muscle their edges will either remain in contact or require but little artificial aid in maintaining this position. "Langer's investigations into the direction in which the skin splits show that the tension of the skin varies greatly in two different directions: two incisions vertical to each other exhibit a varying retraction of the wound-margins; while one gapes widely, the edges of the other remain in contact even without artificial means." . . . . "Fortunately, the course of the nerves and vessels largely coincides with the direction in which the skin shows the greater tension."[1] Skin and muscle gape most widely when divided, the one across the line of cleavage, the other at right angles to its fibres. Gaping is greater when there is much inflammatory tension of the subjacent parts.

Union of Incised Wounds.—The hemorrhage having been arrested, the wound, accurately closed, drained if necessary, kept aseptic and at rest, unites without suppuration by simple adhesive inflammation. If the epithelial covering be thin, the edges may occasionally present for the first twenty-four to seventy-two hours a faint blush, but this is often absent. They are perhaps slightly swelled, are hotter and tender on pressure, but are devoid of pain: sometimes all these symptoms are absent. Even at the end of three days, although the union seems firm, the wound-edges can be pulled apart—the union is mechanical, not vital, resulting from the gluing together of parts by cellular exudate and fibrin. If undisturbed, in a few more days a narrow reddened streak indicates the position of the former cut, the color fading in time into white until the scar almost disappears. This process is primary union, or "union by first intention," and an attempt to secure it should always be made. If perfect coaptation, drainage, and asepticism be impossible, the faintly-reddened margins soon show a decided inflammatory blush; the edges become swollen and tense, throbbing pain is complained of, union fails to occur, and pus forms. A chill or rigor may occur, and headache, fever, anorexia, coated tongue, constipation, scanty high-colored urine, with nervous symptoms varying from mere restlessness to slight delirium, indicate that septic traumatic fever has supervened. If, now, effective drainage and antisepsis be instituted, all the symptoms will decline: granulations form; the wound-margins are no longer elevated, but rather depressed; the masses of granulations level the inequalities of the depths of the wound; the deeper layers become converted into young connective tissue, which contracts, thus lessening the superficial area of the wound; epithelial cells extend inward from the margins until cicatrization is completed, first a red, and finally a white, scar remaining. This process constitutes healing by granulations, or "healing by second intention."

In brief, the process of repair by primary union is as follows: A small quantity of exudate, containing fibrin-forming constituents, coagulates, temporarily gluing together all surfaces which are in apposition, the excess of exudate, if any, being drained off. Leucocytes collect along the line of the wound, gradually increasing in numbers until many of the original tissue-elements disappear, leaving only a mass of so-called "indifferent cells" lying in the meshes of a granular or fibril-

[1] Kocher's *Operative Surgery*, 1894, p. 29.

lated reticular intercellular substance. At first these cells receive nutriment indirectly from the blood-vessels through the plasma-canals described by Thiersch, which are themselves in direct communication with the blood-vessels. While granulation tissue contains leucocytes, the weight of evidence favors the view that the cells of granulation tissue result from the proliferation of the fixed connective-tissue cells and possibly those of the parenchyma of organs, the leucocytes serving as food for these cells. Soon capillary loops develop from pre-existing blood-vessels, penetrate the masses of cells, and pass across from one side of the wound to the other. *Pari passu* with this spindle-cells develop from the round-cells. Most of these spindle cells, in turn, disappear as the new fibrous tissue forms, either by conversion into this or by granular degeneration and absorption. On the surface of the wound new epithelial cells are formed from the deeper layers of the rete mucosum, sometimes under a scab of dried blood and exudation-material, beneath which the young cells remain undisturbed until fully developed, when this portion of the process is essentially what has been termed "healing under a scab" or "by scabbing."

If too much exudate, serous or primarily more solid, is allowed to accumulate in a wound, the mechanical bond effected by the fibrin is broken down, thus delaying union; if excessive congestion occur, much more if inflammation results from any cause, this mechanical disturbance from excess of exudate is probable. It also favors infection and interferes with the processes of repair. The same processes occur in wounds with loss of substance or where primary coaptation has been neglected. In lacerated and contused wounds the damaged tissues must, indeed, be first removed, which is effected—whether they be hard, as bone, or soft, as cellular tissue—by the accumulation, at the junction of the dead and living tissues, first of numerous leucocytes, then of cells gradually forming granulation tissue, substituting the tissues at such points. Finally, the intercellular cement or reticulum of the boundary layer of cells dissolves, loosening the slough, which floats away in the liquid exudate, leaving a layer of healthy granulations beneath. When situated upon a free surface healthy granulations present a level, slightly granular surface, which does not project above the margins of the wound; they are of a pink color, a small amount of creamy pus being secreted if infection has occurred, or an opaque serous or occasionally viscid fluid in aseptic cases. The margins are smooth, shelving, uninflamed, and an advancing border of bluish-white new epithelium is present.

Healing by Second Intention.—This is the normal method where loss of substance has occurred either from accident, operation, or where gaping results from failure of primary union. While it is usually stated that the wound "fills up," the fact is that, although this occurs to a limited extent, the organization of the deeper portions of the granulations causes a marked diminution in area of the surface and a drawing down of the margins, leaving a much smaller surface to be covered in by epidermis than is usually supposed. Upon this organization into scar-tissue of the granulations, and their uninterrupted subsequent contraction, depends the healing of many ulcers. Healing by granulation is then the rule in contused and lacerated wounds, and in incised wounds

whose surfaces cannot be coaptated or where primary union has failed. When two surfaces covered by healthy granulations are held in contact, fusion often occurs; loops of blood-vessels pass from one side to the other, fibre-cells stretch across, and the wound promptly closes by *secondary adhesion*, or "*by third intention.*" This process is purposely utilized in certain cases, "secondary suturing" being employed for coaptation.

Treatment of Incised Wounds.—First arrest the hemorrhage, then cleanse the parts by a gentle stream of sterilized or antiseptic water. Never distend a wound-cavity. Remove foreign bodies with forceps; do not rub the surfaces with a sponge. If the dry method of operating be preferred, of course no water is employed, the wound being cleansed with pledgets of sterilized gauze, etc. Where the wound is irregular and deep, especially in not very vascular parts, one of two courses must be pursued—viz. either all spaces where blood and serum can collect must be effaced by buried sutures, or some means must be provided for the free escape of blood first, and serum later; which latter is expressed from the clots or exudes from the irritated surfaces: the coagulable material probably contains nucleins enough to destroy germs, but the serum does not.

Drainage is not usually necessary for more than twenty-four to forty-eight hours. If, however, infection has occurred and disinfection cannot be assured, drainage is certainly indicated until the dangers of sepsis are passed. When only blood and serum need removal, capillary drains will suffice, but these must never be employed for pus, tubes being here relied upon. A capillary drain may be either absorbable or non-absorbable, the former being composed of fine catgut, the latter of sterilized horse-hair. From ten to twenty or more strands of fine gut should be secured in the middle by a single ligature threaded on a needle, whereby the drain is sewed to the deepest portion of the wound. Between the buried sutures, if such are employed, three to four strands are brought to the cutaneous surface. Each set of strands is now included between two interrupted sutures, the individual threads are laid carefully *parallel and in contact*, and the ends cut off square about an inch beyond the margins of the wound. To prevent drying, and thus converting the strands into narrow tapes which will not drain, the protective must extend some distance beyond the ends of the drains. Employed in this manner, amputation or other large wounds can be readily drained. When tubes are used, they must only reach into the cavity to be drained, and be cut flush with the surface; must be there secured by a stitch or safety-pin; had better—as in amputations of the breast—be brought out through a special incision at the most dependent portion; must be of glass if likely to be kinked or flattened by pressure; and must be removed at the earliest possible moment. When used for pus-cavities they must be gradually shortened. For superficial wounds, especially in vascular parts, for absolutely aseptic wounds, and where by buried suture all spaces are effaced, they are unnecessary and injurious. Some surgeons employ both tube and capillary drainage, removing the first within twenty-four hours and leaving the absorbable drain, or, if horse-hair be employed, pulling out a few hairs at a time during subsequent dressings. Placing the parts

at perfect rest, as on a splint, compresses, and gentle but firm bandaging will aid in doing away with drainage by securing prompt union of the deep as well as of the superficial parts. Aseptic or antiseptic dressings in amount proportioned to the probable extent of oozing must be applied.

The closure of incised wounds may be effected by sutures, which may be interrupted or continuous. The ideal method of suturing is to unite, by buried sutures, muscle to muscle, fascia to fascia, and skin to skin, neither inverting nor everting the latter. Buried sutures of the skin, passing the stitches so as to include merely the dense corium, but not the epithelium, are preferred by many surgeons because of lessened chances of stitch-abscesses resulting from infection by germs resident in or upon the skin, and the avoidance of the scars left by the punctures.

Coaptating sutures must never be drawn too tight, lest they imperil the vitality of the included tissues, thus favoring suppuration. In a thoroughly aseptic wound any pliable aseptic material will serve for sutures, as silk, silkworm-gut, catgut, kangaroo or dog-tail tendon, but non-absorbable substances may at any future time give rise to trouble, so that where kangaroo or other tendon has sufficient stability for the purpose it should be employed, and next to this Chinese twist silk. Needles may be straight, curved, or partially curved, according to whether the wound be in a free surface or a concave or convex one, and should never be larger than requisite to carry the thread. The Hagedorn needle is coming into vogue, and serves a good purpose in many situations, but often makes too large a wound. A round sewing-needle is best for all operations on the bowels, bladder, or peritoneum. Sutures may, in certain localities—as, for instance, the scalp—be substituted by strips of gauze fixed first on one side of the wound by collodion; the lips are to be approximated by traction on the strip, which must then be secured on the opposite side by more collodion. After removal of sutures the same means can be employed to support the wound. Adhesive straps should never be used to draw a wound together, but may be employed to take strain off the stitches or to support the recent scar by interposing several layers of antiseptic or aseptic gauze. Antiseptic compresses and proper bandages, exercising pressure through layers of elastic materials, such as cotton, oakum, etc., sometimes serve as succedanea to suturing by maintaining quiet of the deeper parts, promoting drainage, and relieving strain upon the stitches.

Essentials requisite for good wound-dressings are that they shall be absorbent—*i. e.* favor drying, which interferes with germ-growth—and that they shall contain germicidal substances, preventing infection of the discharges, which in turn may reach the wound: both of these properties render frequent dressing unnecessary, thus giving *rest* to the wound. Sterilized iodoform promotes drying of the secretions, and, if sepsis occurs, will help to destroy the resultant ptomaïnes. One indication for changing the dressings will be their penetration by the discharges, but if the discharge is slight and prompt drying occurs at the margins of the stained area, a pad of fresh antiseptic gauze may be secured over that part if it be undesirable to uncover the wound. Again, if the temperature indicates trouble which is not explainable by complications located elsewhere, the

wound must be inspected, lest drainage be defective or infection may have occurred.

Constitutional Treatment.—During the first few days simple, easily-digestible liquid or soft diet is indicated, after which, if the bowels act normally, fever being absent, ordinary full diet may be given should the patient desire it. If loss of blood or previous drain of pus has occurred, forced alimentation may be requisite, with stimulants, as alcohol in some form, and such drugs as ammonia, strychnia, digitalis, quinine, etc. Watch must be kept that the bladder is properly emptied—that the renal and alvine secretions are normal in character and quantity. Proper sleep must be secured, especially for the young and the old.

Treatment of Lacerated and Contused Wounds.—As some contusion is present in most lacerated wounds, the treatment of both varieties will be considered together.

The cleansing and rendering these wounds thoroughly aseptic is a most difficult task, which is too often but partially done: still, every reasonable effort must be made. Tube-drainage must be employed unless the wound be so shaped and situated that it will drain itself. The apparently hopelessly damaged tissues may be removed, except about the face, mouth, and scalp, where the vascularity is such that nothing had better be removed. Possibly slight trimming of the margins of a face-wound in order to secure primary union may be permissible, but unaided nature will here do marvels, and subsequent deformity may later be removed by operation. Sutures are rarely advisable or necessary, except in the face, where their judicious use will often secure a good result. Rest to the part, with a voluminous dressing, outside of which dry cold may be applied, is often useful, lessening the severity of the inflammation and consequent sloughing. With extensively contused wounds cold must be cautiously employed, lest the sloughing be increased. Where contusion is the chief feature but little primary hemorrhage occurs, as is also true of lacerated wounds, but much blood is extravasated in the tissues. This interferes with the circulation in the tissues; hence sloughing is more apt to be extensive than in lacerated wounds, so that secondary hemorrhage, when the sloughs separate, is an accident to be dreaded. Suppuration and destruction of tissue by sloughing are apt to occur in both classes of wounds, despite all efforts to secure antisepsis. Such complications as spreading cellulitis or gangrene, or any variety of sepsis or infection, are all possible. Extensive scarring especially follows contused wounds. When feasible, if spreading cellulitis with free suppuration occurs, antiseptic irrigation or the continuous bath—warm or cold according to the condition as to sloughing, etc.—is often better than an ordinary closed dressing.

Punctured Wounds.—The depth of these wounds is greater than their width. They are produced by pointed objects, as knives, bayonets, awls, nails, umbrella-sticks and walking-canes, splinters of wood, pins, etc. The dangers of these wounds are—hemorrhage from deep vessels, damage to important nerves, penetration of cavities, and deep, spreading suppuration. When inflicted by a sharp uninfected instrument as a trocar, they pursue a course similar to other wounds, but when resulting from a rough object, such as a board-nail, the end of a stake, a carpenter's rule, and like objects, the results differ, because often fragments

of clothing, the inner sole of a shoe, or fragments of the more superficial tissues are torn off and deposited in the depths of the wound. It is this fact, rather than because the various planes of tissue change their relations after the wound has been inflicted so that exudates cannot escape, which explains the gravity of punctured wounds. Hence for therapeutic purposes punctured wounds must be divided, as Van Buren teaches, into the smooth and the rough.

Treatment.—Hemorrhage having been arrested and asepsis secured and maintained, nothing beyond securing rest to the parts by splint or position is requisite for the smooth variety. If infection has occurred, symptoms of deep cellulitis or of pleuritis or peritonitis will develop, according to the parts involved, in which case the therapeutics of these conditions are indicated. Rough punctures, where foreign bodies or fragments of dead tissues may be present to act as infected foreign bodies, must be treated by effectual disinfection, a drainage-tube introduced to the *bottom* of the wound, absolute rest of the part, perhaps supplemented by primary counter-openings, and certainly by a sufficient number of these later on if deep suppuration occurs.

POISONED WOUNDS.—These are treated of in the chapter on "Septicæmia, Pyæmia, and Poisoned Wounds," by Dr. Carmalt, and will be but briefly referred to here. Formerly, when no preservatives were employed in the preparation of bodies for dissection, so-called dissection-wounds were common and serious. At present post-mortem examinations of bodies recently dead from infective diseases are practically the only source for these wounds. For a short time after death the infective micro-organisms can maintain their virulence, but the bacteria of putrefaction soon replace them, after which only local inflammation can result from wounds contaminated during post-mortem examinations. The bodies of those dying of septicæmia, pyæmia, septic peritonitis, or of erysipelas have proved the most dangerous. Those in vigorous health and in the habit of performing post-mortem examinations are rarely affected—*i. e.* they have an acquired immunity from frequent exposure.

Symptoms.—These vary with the previous health and the poison. Sometimes a pustule forms, ruptures, scabs over temporarily, and a painful inflamed ulcer forms, persisting for months; again, a wart-like mass forms, both conditions being often tubercular. A combination of local and systemic infection is more common, where the puncture or wound becomes inflamed and suppurates; the superficial or deep lymphatic vessels, or both sets, become involved; the lymphatic glands enlarge and often suppurate; while early in the case a sharp rigor, followed by fever, and perhaps sweating, is common. Some cases belonging to this class have a repetition of rigors; a typhoid state is early developed, with multiple glandular suppuration, and purulent peri-adenitis involving the axilla, neck, and side of the thorax. In some of the more serious cases neither distinct local symptoms nor involvement of the lymphatic vessels precede the onset of the constitutional symptoms and the axillary adenitis, etc.

The **prognosis** in this last class of cases is bad, death often taking place in from a few days to three or four weeks. More rarely recovery ensues, leaving an impaired constitution for long periods or for life.

Treatment.—When the injury is recognized at the time, encourage

ling, cleanse carefully by prompt soaking of the part in the able germicidal solution attainable, followed by a moist anti- ssing. Sores and warts must be destroyed by caustics or curet- th. The brawny indurations of cellulitis must be freely incised, ts be opened and drained, and sloughs be allowed exit. Measures o the maintenance of the patient's strength must be used, such ants and good, easily-digestible food. Cardiac stimulants— quinine, and digitalis—are invaluable. Sleep must be secured liminating powers of the skin, bowels, and kidneys called upon.

SIONS.—These are subcutaneous lacerations, the skin surface unbroken. They are caused by blows with hard, blunt r by violent compression. The connective tissue with its iffers most, but muscles, veins, arteries, and lymphatics may erated, the nerves escaping as a rule. Every grade, from a ise to a pulpefication of the part, may occur. In the slighter ew vessels are ruptured, producing swelling and discoloration rts. In other instances, where the tissues are lax or the injury as in a crush of a limb, the major part of the skin may be ff from the deep fascia and the intermuscular spaces be dis- such an enormous extravasation that death results from the bstraction of blood from the circulation.

a blood-collection becomes circumscribed by condensation of nding tissue, it is called a hæmatoma, in certain regions, as the iving a prefix, as cephal-hæmatoma. When the pressure of vasation prevents further effusion of blood, this usually clots, king down into a thick reddish fluid.[1] Absorption is the rule tissues have their nutrition seriously impaired, the extravasa- rge, or in *predisposing conditions* infection occurs, when sup- will take place. When the pressure is great, so that the nutri- e skin stripped from the subjacent tissues is much impaired, n through which infection occurs, or the germs may reach this *oris resistentiæ* through the circulation. In certain localities more readily than in others, as in the thoracic and abdominal ephalhæmatoma in infants never appears to suppurate.

ritated tissues sometimes develop a layer of granulation tissue ie effusion, which may be converted into fibrous tissue, or in alhæmatomata into bone. The central liquid portion becomes d, and if surrounded by a sac of fibrous tissue a serous cyst . This may remain unchanged, or, the fluid contents being sorbed, a dense mass is left, which in time perhaps undergoes .

toms.—The pain, unless a nerve-trunk is involved, is depend- the tension. This, in turn, is due to swelling, which varies amount of blood effused and the laxity of the tissues. The ion promptly appears if the bruise be superficial, but may not until many days have passed if only the deeper parts are or the extravasation occurs beneath a dense fascia. First dark e color changes to green, then to yellow, finally fading out. If ssel be concerned, the loss of blood may be very dangerous, l, as in a case of my own where the external iliac vein with

[1] Allin states that this changes to a lighter hue when exposed to the air.

the deep circumflex artery was torn. The extravasation occupied the whole lower extremity, and formed an enormous subperitoneal hæmatoma. Fever is usually in proportion to the extravasation and laceration of tissues—*i. e.* the amount of fibrin-ferment and nucleins absorbed. When near the surface the overlying skin presents the evidences of a plastic inflammation, which soon disappears unless infection causes suppuration.

Treatment.—Rest for the part, and spirit and water or diluted lead-water lotions so applied as to permit constant evaporation taking place, serve best for the more superficial varieties. In the more severe cases gentle elastic pressure, effected by bandages applied over a thick layer of cotton-wool, after having emptied all blebs and protected them antiseptically, often checks the effusion and promotes absorption. Because in severe contusions portions of the skin may have been killed, light antiseptic dressing must always be applied to obviate accidental infection. Where the tension compromises the integrity of the parts or suppuration seems imminent, aseptic aspiration, followed by pressure, is indicated. When the collateral circulation is seriously interfered with, as the blood probably comes from a large vessel or vessels, incision, ligatures, and proper drainage and asepsis are indicated.

Traumatic Delirium.

This, which sometimes follows certain injuries or operations, results from several distinct conditions. Thus it is a symptom of septic traumatic fever, when it usually becomes pronounced during the height of this—viz. from the second to the fifth day—subsiding with the fever producing it. It is most marked at night, and is usually in proportion to the pulse and temperature.

Prognosis.—This is favorable if the cause is removable, as is usually the case.

Treatment.—Disinfection and drainage of the wound, with cold to the head, laxatives, and possibly diaphoretics or diuretics to aid in the excretion of ptomaïnes, are all that are requisite. Accidental or operative traumatisms inflicted upon those previously subjected to prolonged brain-work, especially if of a susceptible nervous temperament, occasionally give rise to a delirium sometimes called *nervous traumatic delirium*. This occurs without fever and in those not addicted to the use of alcohol. While usually low and muttering, the delirium may be violent, even maniacal.

Prognosis.—This is usually favorable, especially if sufficient sleep can be secured.

Treatment.—Carefully-selected, nourishing food, with stimulants if requisite, will improve the nutrition of the nervous system, which has suffered from the previous over-strain. While this is being effected the cerebral centres must be kept at rest, to prevent exhaustion, by the judicious use of opium, bromides, chloral, or a combination of the last two. Quiet of mind and body should be maintained.

Delirium Tremens, or the delirium occurring in alcoholics, is characterized in its uncomplicated forms by the absence of fever, but it must not be forgotten that it may occur after a serious injury, which in itself produces fever. The delirium is usually of the low muttering, busy,

vigilant form, with delusions, the patient seeing snakes, insects of all kinds, animals, or devils, constantly conversing with himself, and, while capable of answering rationally on other subjects than his delusions, when left to himself promptly becoming again incoherent. At times maniacal outbreaks occur, with suicidal and murderous impulses, usually resulting from injury received during alcoholic excesses: this is true *mania à potu*. Such apparently suicidal acts as jumping from windows are often only efforts to get away from pursuing devils or imaginary persons threatening bodily injury. Unless restrained, the patient will not remain in bed, making efforts to get up despite a broken limb. The skin is moist, the hands shaking; the tongue when protruded is tremulous, coated with creamy fur at first, later, in bad cases, dry, brown, and covered with sordes; the pulse is full, soft, and quick; and the temperature is about normal. The face and whole manner indicate suspicion and fear. Constipation is the rule; complete anorexia is present, although fluids may be greedily swallowed, and sleep is impossible.

Prognosis.—If the patient is young and has sound kidneys, recovery is the rule, but when the reverse obtains death by exhaustion is not uncommon.

Treatment.—In drunkards attention to the bowels, anodynes to produce sleep, proper food, and lessening (but not stopping) stimulants will often ward off an attack, which the experienced surgeon anticipates in those tremulous, sleepless individuals so often brought into our large hospitals. Traumatisms inflicted upon individuals who are only moderate drinkers often suffice to bring on delirium tremens, which otherwise would never have occurred. Sudden withdrawal of the accustomed stimulant sometimes precipitates an attack.

During an attack two indications are imperative—viz. to induce sleep, thus preventing fatal exhaustion of the nerve-centres, and to maintain their nutrition by proper food. A laxative or an enema should be given, and, as liquids are usually acceptable, the patient can be induced to take beef-tea or meat-broths, which, in the case especially of old drunkards, will be rendered more palatable by considerable quantities of cayenne pepper, this condiment acting as a stimulant of both digestion and the circulation. Occasionally forced feeding with the stomach-tube may be requisite. With the older patients, where the kidneys are apt to be damaged, opium is not advisable, but in young, sound patients the hypodermic use of morphia may prove useful. Chloral, in from 15- to 20-gr. doses, combined with potassium bromide, every two hours until sleep is induced, and carefully watched, is usually both safer and more prompt in action. While it may be safe to at once withdraw all stimulants from the young and robust, such practice is not wise in the old or in feeble patients. That stimulant which the individual is accustomed to should be given, but in smaller quantities than usual, and it should be gradually withdrawn. After securing prolonged sleep, tonics, good food, and gradual stoppage of stimulants will usually effect a cure. The judicious use of strychnia hypodermically will aid this, while supporting the heart and nervous system. While it may be possible to secure to the bed a patient who has a fractured limb, it is exceedingly difficult to avoid further injury to this, a simple fracture often being converted into a compound one. Where, owing to restlessness, well-padded splints cannot be em-

ployed—for the patient will probably break a gypsum dressing by pounding the limb about—the limb must be enveloped in an antiseptic dressing and then firmly bandaged in a feather pillow. If now the injury be rendered compound, no special harm will result. Securing patients to the bed by appropriate apparatus will often be requisite, as they will get up and walk even upon a broken limb.

Traumatic Hysteria.

This term is applied to the nervous symptoms often observed after severe physical shock, especially when combined with mental shock.[1] As such combinations are more frequent after railway accidents, the term "concussion of the spine" has been until recently often applied to the condition, or "railway spine," but similar cases result from other forms of accident. Physical injuries to the nervous system, or the results of such, as inflammatory or degenerative changes; the arousing of latent pathological conditions, with all distant injuries of peripheral nerves giving rise to reflex effects; or an ascending neuritis causing central trouble,—must not be confounded with traumatic hysteria.

Neurasthenia, arising as it does from "a general defect in the nutrition and action of the nervous system," must not be confounded with traumatic hysteria. According to Thorburn, the following complexus of symptoms is, with slight variations, constant after many injuries, especially railway ones; it follows those of shock, showing exhaustion of the nervous system, but usually soon disappears under "time" treatment, and must be carefully distinguished from hysteria.

Symptoms of Neurasthenia.—These are "general debility, confusion of thought, loss of memory, mental irritability, disturbed sleep, dreaming, headache (usually posterior), interference with visual accommodation, photophobia, palpitation, frequency of pulse, dyspeptic troubles (furred tongue, foul breath, constipation, and nausea or epigastric pain), sweating, a concentrated condition of the urine, etc."[2] While neurasthenia is often associated with hysteria, and is much more frequent than the latter, it is probably a distinct condition, hysteria being due to "suggestion" or "auto-suggestion," and neurasthenia to mere exhaustion.

Age predisposes to traumatic hysteria and neurasthenia, these affections belonging chiefly to middle life. Hysteria is more likely to occur in females if injured, but as more males are exposed to the causes of traumatic hysteria, more men actually suffer from it. A neurotic temperament and chronic alcoholism both favor traumatic hysteria, as they do the ordinary form, but do not have so much influence as in the latter variety, especially the neurotic temperament. The exciting cause is

[1] Oppenheim calls these troubles traumatic neuropsychoses. Thorburn classifies functional neuroses following traumatisms as follows: 1. Acute effects: (*a*) general nervous depression—"shock" or "collapse;" (*b*) a more localized and defined disturbance of cerebral (cortical) origin—"acute hysteria" or "hysterics." 2. Chronic after-effects: (*a*) general nervous depression—"neurasthenia;" (*b*) a more localized and defined disturbance of cerebral (cortical) origin—"chronic hysteria." Thorburn's definition of traumatic hysteria is: "A functional affection of the nervous system resulting from an injury, due probably to a change localized in some portion of the cerebral cortex, and manifested by correspondingly well-defined and localized symptoms."—*A Contribution to the Surgery of the Spinal Cord*, Wm. Thorburn, B. S., B. Sc., M. D. (Lond.), p. 186 et seq.

[2] Thorburn: *Op. cit.*, p. 185.

some accident, but mental impressions have a large share in the causation of traumatic hysteria; thus Thorburn insists that a previous period of terror, horrible surroundings, and the instantaneous occurrence of the accident have more effect than the physical injury. Direct injury to a nerve-trunk is a "potent cause" of hysteria. While the severity of the traumatism itself has no special determining influence, the locality has, "complete hemianæsthesia or double monoplegia" on the same side as that of the lesion often occurring after head-injuries. Surgical operations are traumatisms, and often give rise to various functional neuroses.

Symptoms.—While the ordinary screaming, laughter, crying, or possibly convulsions so often observed after accidents are evanescent and of no moment, leaving at most some temporary nervous exhaustion, there are certain peculiarities observable at times, especially after railroad accidents. Thus patients will maintain that they have been unconscious for a longer or shorter period, yet investigation shows by the absence of vomiting, relaxation of the sphincters, etc. that this condition could not have been due to cerebral concussion. Such patients walk, travel long distances, do many voluntary acts almost automatically, sometimes regaining their consciousness, as they describe it, after a considerable interval of time and distance of space. They present a peculiar dazed appearance—in fact, resemble in many ways those in the somnambulistic state. Exaggerated or purely imaginary statements are made pertaining to the accident. These illusions are probably the results of "auto-suggestion" during a state closely approximating that of the "minor degrees of hypnotism."[1] These preceding conditions have been called acute hysteria, while those following belong to chronic hysteria.

It will be impossible to more than mention the chief manifestations of chronic hysteria. According to Thorburn, they may be—(1) psychical, including epileptiform attacks and hysterical insanity; (2) motor, including paralysis and contractures of the limbs and special effects upon the larynx and the bladder; (3) sensory symptoms—anæsthesia, hyperæsthesia, and paræsthesiæ of the general or sensory nerves; and (4) vasomotor, secretory, and trophic troubles."[2] In most cases symptoms suggestive of combined neurasthenia are present.

Prognosis.—Under favorable circumstances, with proper treatment, and when pecuniary compensation is not sought or is promptly granted, recovery seems frequently to take place. Chronic alcoholism, a distinct neurotic tendency, and the male sex are unfavorable. Marked changes in severity of the symptoms, transference from one side to the other, and temporary disappearance afford grounds for a favorable prognosis.

Treatment.—Isolate from friends and relatives, encourage use of any paretic part, discountenance the idea that true paralysis exists, employ massage and faradism, secure prompt settlement of legal questions, give tonics, possibly employ overfeeding, and eschew bromides unless necessitated by "much cerebral excitement," when "bromide of ammonium appears preferable to the potash salt."[3] Hypnotism and "transference" have been claimed to be efficacious in some cases.

[1] Thorburn, *op. cit.*, p. 194. [2] *Op. cit.*, p. 194. [3] *Op. cit.*, pp. 224, 225.

Hemorrhage.

This may be arterial, venous, or capillary, or may arise from all these sources. Unless arteries of a certain size are divided, bleeding from them and from the veins spontaneously ceases and capillary oozing alone persists. Hemorrhage is called external when occurring upon a free cutaneous or mucous surface—internal when the blood is poured into such cavities as those of the abdomen, pericardium, pleura, or mediastinum. This term is sometimes also applied to hemorrhages into hollow viscera, as the stomach, intestines, or bladder. When blood is poured out in small amount into the cellular tissue ecchymoses or bruises result, while if the amount be large the term "extravasation" is employed. Traumatic hemorrhages are called "primary" when immediately following the injury; "intermediary" when they occur between the stage of shock and that marked by suppuration, the bleeding resulting either from the increased vascular tension of reaction or from coagula occluding vessels becoming loosened by the premature removal of external pressure; "secondary" when they occur after suppuration has been established, being due to separation of sloughs involving the vessels, or to septic or infective inflammation of the vessels, leading to their ulceration or rupture or to the solution of the occluding thrombi; "parenchymatous" when there is a general capillary oozing, due either to inflammatory dilatation and canalization of the smaller vessels or to thrombosis of the principal vein or veins.

Treatment of Hemorrhage.—Great losses of blood are dangerous because of the risk of fatal syncope. This must be combated by the retention of a functioning amount of blood in the brain, especially in the respiratory centres. The head and shoulders should be promptly lowered, and this position maintained by elevating the foot of the bed some inches, neither pillow nor bolster being left beneath the head. The limbs should be raised nearly to a right angle with the body, and thus held. Sometimes, instead of this, Esmarch or ordinary muslin bandages can be applied to one or all of the limbs, or digital or instrumental compression of the arteries of the limbs may be substituted. Many lives would be saved if the more essential, if not all, of these measures were instituted where the accident has occurred, instead of waiting for removal to a hospital, house, or even to a couch.

Next, stimulants by the mouth or rectum must be employed. Turpentine rectal enemata act well. Subcutaneously, whiskey, ether, atropia, and strychnia will prove beneficial. Artificial heat by hot bottles, and a sinapism over the heart, are useful. Transfusion of a saline solution into the cellular tissue of the pectoral or abdominal region, by means of a hypodermic needle attached to a few feet of small rubber tubing and a funnel, acts nearly as well as intravenous saline transfusion, and is much more readily done: indeed, considerable quantities of sterilized normal salt solution may be injected in a short time by the rapid use of an ordinary hypodermic syringe. As occasion permits, concentrated hot meat-essences, milk, hot coffee, etc. must be given—*i. e.* liquids which when absorbed will supply the heart with a bulk of fluid sufficient to carry on its functions. As the patient rallies the bandages must, one by one, be cautiously removed, the limbs then lowered, but the dependent position of the head must be maintained until all risk of syncope has passed away.

Later, iron, tonics, and nutritious food are indicated to supply the loss of red cells. Ergot, sulphuric acid, acetate of lead with opium, have all been occasionally useful in recurring hemorrhages where the bleeding points cannot be reached—*i. e.* in enterorrhagia, hæmatemesis, etc.

HÆMOSTASIS.—The local means for temporary hæmostasis are local pressure by fingers, compresses, tourniquets, bandages, etc. over the wound or on the bleeding vessel in the wound; compression of the main vessel above or below the wound by similar measures; and flexion, especially of the elbow or knee, for wounds of the arteries of the hand or foot. A compress should be placed in front of the elbow or behind the knee, and the limb bent until bleeding ceases, the member being thus maintained by a handkerchief or bandage. Only such styptics are permissible as imitate or hasten Nature's efforts, which are, in the case of arteries, lessening of calibre and retraction within their sheaths, with the formation of an external and an internal clot, and in veins their collapse and consequent thrombosis.

Exposure of wounds to the air after removing all clots, a current of cold water flowing over their surfaces, or ice itself in the wounds or applied over the dressings by means of an ice-bag or an ice-bladder, are the best means of employing *cold*.

Hot water (125°–130° F., roughly estimated as the greatest heat bearable for a few moments by the back of the hand), poured over or better applied by pressing a towel wrung out of the water on the wound, acts better than cold and does not depress the vital powers. Alcohol or tincture of iodine pure or variously diluted has been successfully employed by some. Perchloride and subsulphate of iron are popular but unreliable styptics; moreover, they render asepsis and immediate union impossible. While Monsel's solution is useful for free bleeding from leech-bites, it is better even for such accidents to transfix the lips of the minute wounds with fine sewing-needles, around each of which a figure-of-8 ligature should be cast. Tannic and gallic acids are less objectionable than the iron salts, while alum applied by means of cotton saturated in a hot solution has been much vaunted: probably *pressure* has much to do with its efficacy, and an iodoform-gauze tampon would be vastly better. These chemical styptics are only mentioned to condemn them, except where nothing else is available, as will sometimes occur.[1]

The *actual cautery*, applied at a dull-red heat, is most efficient when primary union is not aimed at or in the peritoneal cavity, in the latter case no eschar being separated. The cautery is often the only resort in such operations as removal of the upper maxilla, where the vessels cannot be isolated. The thermo-cautery is the best form, but any metallic substance, as wire, knitting-needles, etc., can be heated in the fire or gas.

Measures for the Permanent Arrest of Hemorrhage.—While the cautery for certain cases and the antiseptic tamponade may be employed for this purpose, certain other measures are more commonly employed.

Torsion.—Only divided vessels can be twisted. Drawing out the whole cut end of the vessel with one pair of catch-forceps, grasp the vessel transversely close to the tissues with a second pair. The end of the vessel can then be twisted off, or three or four sharp turns can be given until the inner and middle coats give way, resistance to further

[1] In bleeders, but here the thermo-cautery would be better.

torsion then suddenly diminishing. Smaller vessels which cannot be isolated can be seized with some of the surrounding tissues, all of which should be twisted off.

Forcipressure is effected by seizing the vessel or tissues with catch-forceps, which can be removed in from a few minutes to forty-eight hours.

Ligature.—Properly-prepared silk, kangaroo tendon, and catgut form the best ligatures. If tying a divided vessel, draw its end out by forceps or a tenaculum just far enough to place the thread securely. If in dense tissues, the tenaculum should be used, and slightly withdrawn as the first half of the knot is tightened. A curved needle armed with the thread can sometimes be more conveniently employed, passing it around the vessels so as to include a little of the surrounding tissues, thus preventing the ligature from slipping. When tightening the knot the surgeon's thumbs or forefingers must press somewhat down against the forceps or tenaculum, so as not to pull the instrument off the vessel or out of its sheath, this latter accident favoring secondary hemorrhage. When the ligatures are to be cut short, whether silk or catgut, the first half of the knot must be tied only so tight as thoroughly to occlude the vessel and maintain its position, damaging the coats as little as possible: when a ligature is to come away, the aim is to divide the inner and middle coats, so that only the external coat remains for the thread to ulcerate through: both modern surgical practice and theory condemn this. A "reef" or "square" knot must be employed to the exclusion of the "granny."

An artery wounded in its continuity must be reached through the wound with the least damage to parts, the proximal and distal ends tied, and also any branch opening into the part included between the ligatures.[1]

Measures for Recurrent or Secondary Hemorrhage.—Ligature of the bleeding points, when feasible, followed by antiseptic tamponade when a cavity is concerned, is the best. As the bleeding from an artery tied in continuity usually comes from the distal extremity, especially when overlying a bone, a graduated compress and bandage may suffice: this may be tried before religation or amputation. If methodic compression is to be employed, control the artery by pressure above, clear out the clots, apply the compress directly on the bleeding point, and secure it by bandages, which must support the circulation of the whole limb, below and above. Not much pressure must be used, and this should be relaxed after twenty-four to thirty-six hours, to prevent the formation of a slough with renewed bleeding; but the compress *must be allowed to come away of itself.* Where no room remains for the application of a ligature, the wound may be filled with shot or a shot-bag employed as a compress. When all means fail, if an extremity is involved, amputation should be done.

[1] *Acupressure* may be used to occlude a vessel, thus: Pass a threaded needle through the tissues beneath a vessel, cast over its point a loop of metallic wire, and compress the vessel by securing the wire by a turn or two around the eye-end of the needle; traction of the thread removes the needle, freeing the wire loop. Again, a long, stout steel pin can be passed through the skin and tissues at one side of the vessel and over it, and be made to emerge through the skin on the opposite side. According to the size of the vessel the needle or pin can be removed in from thirty to sixty hours.

Hæmophilia.

This disease consists in a tendency to excessive and continuous hemorrhages, occurring spontaneously or after traumatism. Swelling of the joints is frequently associated with the external hemorrhages. It is congenital, attacks males, and is usually inherited through the mother, who herself escapes. The first manifestations nearly invariably occur before the second year of life, the primary bleeding rarely appearing after puberty. In fact, after this period the tendency to bleed diminishes. The oozing, continuing for hours, days, or even weeks, is always capillary. Epistaxis is the most common form of spontaneous hemorrhage: slight scratches of the skin, bites of the tongue, leeching, blisters, extraction of teeth, and circumcision are some of the traumatic causes; the last three seem especially dangerous. In the slighter form petechiæ, ecchymoses, and hæmatomata may occur, either spontaneously or from trivial injury. Jenner reports a hæmatoma extending from the knee to the trochanter produced by the fall of a rubber ball on the thigh.[1] The petechiæ, which occur chiefly beneath the skin of the extremities, although sometimes seen on mucous and serous membranes, may be accompanied by swelling and pain in the joints. Either with or without these purpuric spots arthritic complications are very common. These vary from simple pain to suddenly-developed redness and intense inflammation accompanied by fever, thus closely simulating acute rheumatism. The knee-, elbow-, ankle-, and shoulder-joints are those most usually affected. Repetition of the attacks commonly results in marked deformity and disability. With the exception of ordinary anæmia just after the bleeding the blood is normal, wounds healing as in other anæmic patients. Histological examination of the vessel-wall has only once afforded confirmation of the statement of Blagden, made in 1817,[2] that the walls are unusually thin, Kidd[3] finding degeneration of the muscular tissue of the middle coat of the arteries and proliferation of the endothelium of the arterioles, veins, and capillaries. Hemorrhage into or around the capsules of the joints accounts for much of the articular swelling. Inflammation of the synovial fringes and ulceration and destruction of the articular cartilages have also been reported.

Pathology.—Although there must be some peculiar frangibility of the vessels and failure in prompt coagulation of the blood, there are no histological or chemical facts explaining what these abnormalities are.

Diagnosis.—In a bleeder family this is easy. If occurring in a member of a family hitherto free, and not resulting from slight prolonged sepsis, reliance must be placed on these points: The spontaneous or traumatic hemorrhages are multiple, joint complications are frequent, the tendency to bleed persists for years: this would constitute a congenital bleeder, not an hereditary hæmophiliac, and if a male, he would be likely to found a "bleeder family" if he should have offspring. The differential diagnosis from simple hemorrhagic or infective purpura, peliosis rheumatica, etc., must be sought elsewhere.

Prognosis.—Few die from the first bleeding. The older the patient the better the chances, especially in girls, who do not seem specially

[1] Legg: *On Hæmophilia*, p. 68. [2] *Medico-chirurg. Trans.*, vol. xli. [3] *Loc. cit.*

prone to post-partum hemorrhages, although often menstruating early and profusely.

Treatment.—Prophylaxis is imperative; all operative injuries, extraction of teeth, and anything but life-saving operations must be interdicted. In the presence of hemorrhage cleansing of the wound, followed by pressure, should be employed. Antipyrine may do good, while repeated injections of cocaine into the gum has checked the oozing after pulling a tooth. Ergot by the stomach, purges of sodium sulphate—except in enterorrhagia—large doses of tincture of chloride of iron, have all seemed to do good. Tonics, iron, cod-liver oil, etc. are indicated after the attacks, with residence in a warm climate. The joint-troubles must be viewed as grave. If absolute quiet with moderate compression be employed, a first attack often leaves an articulation normal, but when untreated or repeated bleedings occur an arthritis results resembling some forms of tuberculosis.[1] While a very dangerous procedure, König has thrice punctured the joint, using antiseptic irrigations, and has had two cures and one improved case.

Bertrand[2] and Pilcher[3] think that the dangers of capital operations are overrated, because the larger vessels bleed no more than in ordinary patients. While operations should be avoided when possible, if they are requisite careful ligation of the smallest vessels, with firm compressing bandages to control parenchymatous bleeding, will often suffice. If necessary, the actual cautery and tamponade with gauze impregnated with iodoform or chloride of iron will render success more frequent. Asepsis is imperative, "since secondary subcutaneous or intermuscular hemorrhages make the danger of suppuration" greater.

[1] *Med. and Surg. Reporter*, June 25, 1892, F. König.

[2] Hiedel: *Inaug. Dissert.*, 1892, referring also to successes by Cramer, Schede, Czerny, and Müller.

[3] See *Annals of Surgery*, p. 499 et seq., vol. xvii., 1893 (Pilcher), for special means adopted.

SEPTICÆMIA, PYÆMIA, AND POISONED WOUNDS.

By WILLIAM H. CARMALT, M. D.

Septicæmia.

By septicæmia, or septic or putrid fever, we understand a general disease which occurs by reason of the introduction into the circulation of the products of decomposition, and which is characterized by certain definite changes in the blood, a typical succession of inflammatory processes, and a continued fever with peculiar nervous symptoms and cutical secretions.[1]

This definition, in allowing us to include the absorption of the products of decomposition, without the actual presence in the blood of the micro-organisms thereof, conforms to the clinical phenomena as we find them in surgical practice. Cases of extensive subcutaneous lacerations, followed by fever and other clinical phenomena of the absorption of septic material, are of frequent occurrence, yet the most careful investigation does not reveal the presence of infective micro-organisms. These cases are regarded as instances of the absorption of the chemical substances, toxines or ptomaïnes, produced in the decomposition of the blood-clot, poisonous in their action, causing a form of septic intoxication to which Matthews Duncan gave the name of "sapræmia."

In a few hours—variably from twelve to seventy-two—after the reception of a subcutaneous laceration of the soft parts, with extravasation of blood into the connective tissue, or after a surgical operation in which the hæmostasis has not been complete, or—taking an illustration out of strict surgical practice, though of like pathological significance—after the act of parturition, a disturbance shows itself, usually first noticed on the part of the nervous system. The patient has a headache, a flushed face; the appetite fails; there may be nausea; there is a marked feeling of depression, even anxiety; there may or may not have been a slight chill; the temperature is from 100° to 102° F. or more; the tongue becomes dry, and an acute sense of smell will perhaps detect a slight odor to the wound or discharge. If the proper treatment be not immediately instituted, these symptoms increase, though not uniformly so in all cases: headache may not be complained of, but the sensorium becomes greatly blunted; the patient is apathetic, lies rather in a stupor, and, though answering questions intelligently, is slow to be aroused; the nausea becomes more pronounced; the food is vomited; the temperature keeps up all the time, in the afternoon rising a degree

[1] Gussenbaur: "Sephthämie, Pyohämie, und Pyo-sephthämie," p. 2, *Deutsche Chirurgie*, Lief. 4.

or over, ranging between 101° and 103° F.; the tongue becomes drier, perhaps not more coated; the patient at times is delirious, able to answer if aroused, though not always correctly; the pulse becomes rapid and feeble, the respiration hurried and superficial; if drink is offered, it will be taken with avidity, but the patient does not ask for it; the sensorium is benumbed; the muscular strength fails greatly, and the patient sinks down in the bed. In bad cases these symptoms increase rapidly: the benumbing of the sensorium, as shown in the stupor and delirium, becomes greater, the heart's action more feeble; there may be *subsultus tendinum;* the half-closed eyes become glazed with mucus, which collects upon the cornea and around the edges of the lids; if care be not taken, involuntary discharges of urine occur from overflow of the bladder, the patient being unconscious of the distention; the bowels are constipated, and if a cathartic be administered the discharge will be unnoticed; the face, at first flushed, becomes, as the heart's action fails, dusky and livid, and death comes on the fourth or fifth day.

With all these grave constitutional disturbances, however, it is to be remarked that there are but few changes in the wound-surface; the odor of decomposition may remain, or, if the parts are not thoroughly washed, it may increase; but the tissues around the cut surface do not show any changes to indicate that they have become the seat of deposits of micro-organisms, nor does the post-mortem examination show the cloudy swellings in the parenchymatous organs associated with septicæmia. The clinical phenomena are those of the nervous system being overwhelmed by the action of a substance resembling a narcotic poison.

In milder cases—*i. e.* those in which the amount of poison absorbed has not been great, or in which a rational treatment has been promptly and successfully instituted—the symptoms disappear as rapidly; the headache and other nervous disturbances pass off; the appetite returns; the pulse regains its tone and strength, and the temperature becomes normal.

The **prognosis** depends upon three factors:

First: the amount of poison absorbed—as for other poisons, upon the dose administered. Regarding the disease as due to direct absorption of the poisonous products of decomposition, and not to the presence of micro-organisms multiplying in a fertile culture-medium, it is evident that a large dose will have more effect than a small one. This depends, therefore, either on the size of the blood-clot undergoing the decomposing processes, or on the extent of tissue destroyed from which the toxine is evolved to be distributed to the nervous system, upon which, it is evident, it most powerfully acts. In this there is a striking contrast to other more positive septicæmic processes, where a small wound—the prick of a needle or a scalpel in a dissecting wound—is followed later by extremely serious consequences.

Second: the time which elapses before the proper treatment is applied: the longer the poison acts by its depressing influence upon the nervous system, the higher the pulse and temperature become, the more are they using up the patient's vital forces.

Third: the constitutional habit—viz. the strength of the individual to resist the action of the poison. This factor does not require explanation; it is the same for all diseases. The prognosis, of course, is more

unfavorable in the extremes of age or if this disease be complicated with some other.

The treatment consists, first, in removing the source of the disease, removing all blood-clots, and, if it be a wound, washing off the absorbing surface. In this condition the use of germicidal solutions—the so-called antiseptics—is no more beneficial than that of sterilized water. The only advantage they have is in the destruction of any possible germs, or their spores which may not yet have become active, but which, under favorable conditions, are likely to become so and to lead to more serious disease. Blood-clots and all matters which serve as a basis for the development of the products of decomposition must, however, be thoroughly removed and their further collection be prevented.

It depends on the violence of the symptoms as to how far we must go in exposing a raw surface for the purpose of getting rid of the poison: a single thorough washing out of the uterus after parturition is often sufficient to reduce the temperature to normal without a relapse; occasionally it is required to repeat it a few times at lengthened intervals, or in other cases it must be done every few hours. In the case of wounds where we are hoping to get union by first intention, a single washing out, with pressure firmly applied over the skin of the stump (if it be an amputation), will frequently suffice. If this does not answer the purpose, the introduction of a drainage-tube becomes necessary, and more frequent cleansing with the more positive germicides, owing to the danger that septicæmia may take the place of sapræmia. Mercuric bichloride in the proportion of 1 : 2000–10,000, and carbolic acid in from 1 to 3 per cent., are at this period of great value. The further carrying out of local treatment is included in that of septicæmia.

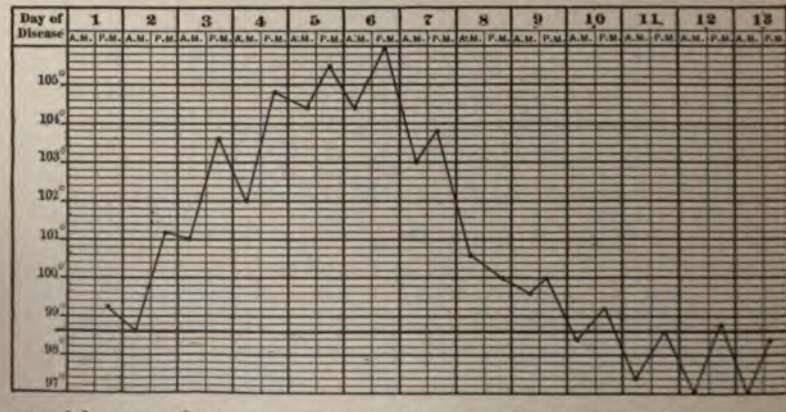
The treatment of the constitutional condition consists in strengthening the action of the heart and that of the general system by the administration of stimulants: whiskey, St. Croix rum, and brandy in milk-punch or egg-nog are preferable, as thereby nourishment is also given; quinia or tr. cinchona is of great value, but the use of the recently-invented antipyretics is of little benefit.

In a certain number of cases, where the amount of poison evolved and absorbed is not sufficient to cause the death of the patient, and in which treatment is not properly instituted for recovery, in the course of some days another condition of the general system is brought about, due to further changes in the blood-clot and in the neighboring tissues. The micro-organisms producing the putrefaction of the clot penetrate in time into the several blood-vessels of the wounded part, there finding a soil more fertile for their further multiplication and development. We then have another set of symptoms, in many respects, it is true, similar to those of the septic intoxication, but with this important difference—that their severity is due not so much to the amount of a poison absorbed as to the activity of growth of the bacteria. In other instances than the one mentioned of a retained blood-clot we find the same set of symptoms following trivial as well as severe injuries—the mere prick of an infected lancet, the most indifferent scratch. I have in mind the prick of a wooden toothpick received in the hand in taking it out of the pocket, necessitating subsequently the amputation of the arm to preserve life: medical literature reports similar cases in abundance. It is only necessary that

the bacteria be given access to the circulation in order that the disease may be set up; an evident wound is not necessary. It must not be understood, however, that all persons thus injured, who are subjected to the same infection, respond equally and are susceptible in a like degree to the deleterious effects. It would seem that all blood is not equally good soil for the growth of the germs, or that the tissues of some persons resist their action, so that the general infection does not follow the exposure, and the individual escapes.

The infection in septicæmia is shown both locally and constitutionally, but not uniformly in either way. It depends largely on the character of the wound, but in some degree also upon the virulence of the infection. In cases of open wounds, such as compound fractures or severe lacerations of the soft parts, including the skin, with contamination of the tissues, a class of wound most frequently followed by septicæmia running a typical course, the skin at the seat of injury becomes reddened, swollen, and painful, and the wounded surface becomes covered with a dirty-looking, somewhat thick secretion, which will partially wash off, but leaves the tissue underneath of a dull, more or less variegated gray color, without distinction between different anatomical parts, with a superficial slough and an appreciable odor of decomposition. This last is an exceedingly important symptom, to be sought for early with great care; and it may be here stated that the great objection to iodoform as a dressing for fresh wounds is that by its strong odor it masks the first positive evidences we have of putrefaction, and in just so far increases the danger of acquiring the general condition of septicæmia. At the time that these changes appear in the wound, or very soon afterward, the general system shows evidences of participation, in that the temperature rises—it may be a degree or two, it may be more—the pulse and respiration are accelerated, the tongue becomes coated, and the patient complains of a general sense of discomfort; in other words, an active febrile move-

FIG. 10.



ment with some, but not severe, evidences of affection of the nervous system, inasmuch as stupor and apathy are not so prominent, in this respect differing from the condition of sapræmia or septic intoxication just described. The fever is continuous, but with morning remis-

sions and afternoon exacerbations, gradually on successive days rising higher and higher—the morning remission not reaching that of the previous day—until the acme is reached: this occurs about the fourth or fifth day, when, with the appearance of suppuration in the wound, the constitutional symptoms abate and the fever subsides by a similar gradation of declining steps at each day, though more rapidly than it arose, so that, while it was from three to six days rising, it falls in from two to four days to a nearly or quite normal temperature. The temperature-chart of a typical case of septicæmia going on to recovery is shown in the accompanying diagram (Fig. 10) of a case of compound comminuted fracture of both bones of the leg by a railroad injury, occurring in an otherwise healthy man of about twenty-five years of age.

The character of the wound, the method or absence of treatment employed, the nature of the infective material with which it is contaminated, and the constitutional condition of the individual as to power of resisting the invasion of the infective micro-organisms and the development of the toxines, are, however, factors that modify the course of the disease, both locally and constitutionally, in a great variety of ways. It is of the highest interest to surgeons to know just how to meet the manifold phases.

The septic process may spread locally along certain definite anatomical lines; it may invade all the tissues of a limb or a part, attacking, perhaps destroying, every tissue that it meets. The most frequent anatomical site, however, is perhaps the connective tissue, where, owing to the loose arrangement of lymph-spaces, vessel-sheaths, and intermuscular planes, the development of the bacteria is given every facility, and where they do grow almost without limit. These are the cases of cellulitis so constantly met with in the hands, less frequently in the feet, of tradespeople and those who are exposed to infection from their occupation. We find them arising from the most trivial, many times undetected, injuries, usually spreading rapidly, with great pain and swelling.

In other instances entrance is gained into the sheaths of the tendons, and tendo-vaginitis of an exceedingly severe character is excited, often going on to suppuration, extending into the palm of the hand, and so on up to the wrist, with the result of the impairment, if not absolute abolition, of function by the destruction of the sheath from sloughing or from the necessary treatment in laying it freely open, the subsequent cicatrization producing adhesions obliterating the sheath, or so attaching it to neighboring parts as to prevent the normal play. These cases are intensely painful, owing to the confinement of the swelling inside the fibrous sheaths, and, while not so deforming as when the connective tissue alone is involved, the integrity of the hand is in greater danger even if amputation be avoided.

The various distributions of the lymphatic system serve frequently, both in common with the connective tissue and alone, as media for the transmission of the micro-organisms: it may be as a simple lymphangitis or lymphadenitis, and we may regard septic osteomyelitis as belonging here. These cases are always serious by reason of the very great facility with which they spread, either continuously along the course of the vessels, or more erratically, leaping from one set of glands to another, sometimes quite at a distance, each set serving as a

focus for the storing up and further distribution of the bacteria. Occasionally they suppurate, though they usually do not, but where they do it simulates pyæmia, and the diagnosis is then difficult. The more acute course, coming on before suppuration has appeared in the wound; the character of the fever, being continuous instead of intermittent; the absence of repeated chills and the torpor of the nervous system,—determine clinically the septic rather than the purulent character of the process, as is confirmed at the autopsy by the absence of abscesses in the parenchymatous organs.

The most virulent form of septic infection, however, appears in the immediate invasion of all the tissues of a part—skin, connective tissue, muscles, lymphatic vessels, and blood-vessels. This invasion is of great gravity, and comes on usually as the result of extensive injuries to both soft parts and bones.

A man of not very robust physique, but otherwise in good health, had his left foot caught between an elevator-car and the floor above in such a way that most of the sole of the foot, including the tuberosity of the os calcis, was nearly crushed off. The ragged skin and enclosed pulpefied mass of bruised tissue were stitched together by an incompetent practitioner, bandaged firmly with cotton roller bandages halfway up to the knee, and left practically without further treatment. He was admitted to the New Haven Hospital on the fourth day after. There was an extremely offensive odor of putrefaction; the foot was black and gangrenous; the whole injured portion and the leg to just above the knee swollen, emphysematous, and of a peculiar shiny-brown or bronzed color—not reddish. This color had been noticed only on the day previous to admission, but had advanced rapidly after making its first appearance. The pulse was about 105, of good force; the intellect clear; there was considerable pain in the leg. The temperature was $100\frac{4}{10}°$ F. A free incision was made about halfway to the knee at the spot where the emphysema was most evident; no pus was found, but the wound discharged a thin sanious fluid of a more or less yellowish color, mixed with gas, and gas could be pushed out of the wound in the foot from above; the incision through the skin scarcely bled; there was no undermining of the skin or opening of the muscle-planes, and it was impossible to get a drainage-tube in without breaking through fresh tissue. An active system of antiseptic irrigation was instituted, but the infection of the tissues continued to advance, and the next morning the discoloration was two inches higher; the temperature a trifle higher, $100\frac{8}{10}°$, the pulse 80, the mental condition still good. That the foot would require amputation was without question, and the advancing infection of the leg made it appear as if it would be necessary to take the leg off high up, above the knee, to save life, but the very rapid advancement left it uncertain just where. In the afternoon the discoloration had reached the irregular line shown in the illustration (Fig. 11) taken from a photograph. At this time the temperature was $101\frac{6}{10}°$, the pulse 115 and more feeble, but there was no stupor or other disturbance of the nervous system other than could be accounted for by the natural anxiety of what the outcome was to be, for it now looked as if the thigh must be amputated in the upper third, if not at the hip-joint. During the next night there was no advancement of the discoloration, and the temperature had fallen to 101°, in the afternoon

to 101 $\frac{2}{10}$°, and from this time there was a steady subsidence of the untoward symptoms, both locally and constitutionally, so that on the ninth day after admission I was able to amputate at about the middle of the leg. The tissues at the site of the operation still showed evidences of

FIG. 11.

Bronzed discoloration of skin of leg and thigh following traumatic gangrene of foot, appearing third day after injury—photograph taken second day thereafter. (From records of New Haven Hospital.)

the diseased condition in that they were infiltrated with serum and did not heal by first intention, but the course of the operation was almost aseptic throughout in that the rise in temperature on the afternoon of the day following the operation was 100 $\frac{4}{10}$° F., falling at the next observation to normal.

The fortunate result in this case cannot be regarded as the rule, however, in cases of general septic infection with traumatic gangrene, as is illustrated in another case, likewise under my care at the same hospital, where a woman of fifty-eight was subjected to the manipulations of a notorious "bone-setter" for a dislocation of the left shoulder-joint of two weeks' duration. After prolonged and violent attempts at reduction the arm was finally left with the elbow bound firmly to the side and a pad in the axilla. I saw it first three days afterward: the arm was then black and gangrenous to the elbow, with great swelling and a reddish discoloration of the arm above. The pain was severe, the pulse of the opposite arm rapid and feeble; the temperature was 102° F.; the patient was alert in mind, aware of her danger, and anxious to have the arm removed; the tongue was already dry, and there had been some vomiting. Amputation was deferred to try—first, to improve the heart's action by stimulants; second, to try the effect of antiseptic treatment in reducing the fever; third, to see if some line of demarcation would not show itself. The first only of these desiderata came about: the heart did gain strength, but the putrefaction increased, the swelling and redness extended over the shoulder, and began to invade the neck. On the first day after admission the temperature was 103 $\frac{4}{10}$° F., falling the next morning to 100 $\frac{4}{10}$° F., and rising in the afternoon to 103 $\frac{8}{10}$° F.; the tongue continued dry. Incisions were made in the arm for the purpose of washing it out antiseptically. It being evi-

dent, however, that the sepsis was increasing, and the patient's general condition not improving, the arm was amputated at about the middle on the second day. At the operation it was found that, instead of a dislocation, there was a fracture of the surgical neck (whether this was the original injury or was produced by the violent efforts made to reduce the dislocation could not be told), and that all the tissues at the line of amputation were infiltrated with a foul-smelling serum, particularly in the intermuscular planes of connective tissue. The bone was removed at the seat of fracture, and the sinus thus left was mopped out with pure carbolic acid, and the wound freely irrigated with mercuric bichloride, 1 : 1000. There was a decided improvement in her condition immediately and for a few days following the operation; the temperature fell to 100° F., but her heart failed; she was soon after attacked with a septic gastro-enteritis, causing profuse watery discharges, which became choleraic later and involuntary; her stomach refused to retain anything; she became indifferent to her surroundings, and finally comatose, dying in this condition thirteen days after the injury, eight days after the amputation. This gastro-enteritis is not unusual in severe cases, and is regarded by Gussenbaur as directly due to the action of the products of the septic micro-organisms upon the intestinal tract.

While these two cases bear, in their local action, a marked resemblance to the *gangrène foudroyanté* of Maisonneuve, there is an important difference in the symptomatology—viz. that the nervous symptoms were by no means so prominent. In the case of the wound of the foot, although the local progress was most rapid, to be seen advancing almost from hour to hour, the patient's mind was clear: he appreciated the danger of his situation, was desirous to have whatever done that his medical adviser deemed best, and was in no way either apathetic or over-anxious as to his situation. In the other case it was not until just before the arm was amputated, five days after the injury, that the torpidity of the intellect as given by Maisonneuve became a prominent symptom. His cases are described as "being from the beginning in a condition of complete apathy; the wound and its parts affected by the septic infection are almost painless; the patient does not ask for drink, though his dry tongue cleaves to his gums," though in other cases there is great restlessness, indeed manifest delirium, with unconsciousness of surroundings and disposition to toss about in spite of the injuries; the skin is bathed in perspiration; the urine and fæces are passed involuntarily; the respiration is hurried and superficial, the pulse weak and intermittent; in other words, there is a condition of extreme collapse, in which the fatal termination appears in from twenty-four to ninety-six hours. In the cases which last long an icteric hue to the skin becomes evident, showing the effect of the poison on the liver, which on autopsy is usually found swollen and soft.

This description is very like that given of septic intoxication (sapræmia), but we are taught that in this the local changes are as nothing. It is therefore evident that the most active fulminating putrefactive local process may go on for days in an extremity, with no absorption taking place of the products of decomposition to affect the cerebral functions, and finally recover; and, further, that symptoms identical with this acute disease, sapræmia, may come on as a secondary fever

several days after the reception of the injury, an intermediary, comparatively afebrile, stage being passed through.

The effect of the septic infection, as has been stated, is much the most marked in the systemic disturbances; the tissue-changes, aside from the direct injury, are not very great. They consist in an interference with or a cessation of the proper process of repair, rather than in active destruction. There are cases, however, where the local destruction is excessive, as in the gangrenous stomatitis or cancrum oris of children. A characteristic instance of this occurred in my service at the New Haven Hospital.[1] We have here to deal with the invasion of the tissues by the bacteria to such an extent as to destroy them *en masse*. It is not a question of a cutting off of the blood-supply by an embolic process, as in gangrene of a limb, nor of the destruction of the vitality of the tissues by a violent force, as in railway injuries, nor, again, of the infection of the system from a trivial injury, as in a dissecting wound, but the almost simultaneous destruction of all the tissues of the part by the apparent invasion of the whole by countless myriads of bacteria of various kinds, staphylococci, streptococci, and micrococci all being found. These cases usually occur in children already reduced in vitality by some debilitating disease, as typhoid fever, but in whom access to the tissues by the micro-organisms is obtained by some slight abrasion—in this the picking at a tooth with her finger-nails produced a slight abrasion which rapidly increased to an area of inflammation, followed by

FIG. 12.

Gangrenous stomatitis following typhoid fever about twelfth day after beginning of ulceration. (Records of New Haven Hospital.)

necrosis and gangrene, so that when I first saw her, about ten days from the beginning of the local trouble, there was an area of gangrene involving the entire thickness of the cheek from near the median line

[1] Dr. C. J. Foote, in the *American Journal of Med. Sciences*, Aug., 1893.

to beyond what had been the angle of the mouth, exposing both upper and lower jaw-bones; the teeth were loosened from their sockets; shreds and masses of necrotic tissue were lying loose in the ulceration; the odor was indescribably offensive; the child lay quiet and somnolent unless aroused, and then shrieked and tossed about in angry delirium; the pulse was 130 and feeble, the respiration about 25, temperature $102\frac{8}{10}$° F.; the skin around the ulceration was swollen and reddened. In spite of energetic treatment the gangrene extended without the slightest check, and in two days the cavities of the nose and mouth were both exposed and the palate was gone; in another the lower eyelid had fallen away from the upper by the detachment of its inner commissure; a large part of both jaws was denuded of periosteum at the bottom of the ulceration, and the bones themselves were already necrotic. The pulse was about 140, the respiration about 40, the temperature varying from 101° to 104° F. On the fourth day after admission the morning temperature was $104\frac{4}{10}$° F., the afternoon $99\frac{8}{10}$° F. She died on the fifth day after admission, about the fourteenth day from the invasion of the tissues by the bacteria. This extensive destruction by gangrene of all the tissues, the blood-supply not being cut off, is exceptional and only found in similar conditions; it would seem that young tissues, especially when reduced by debilitating illness, afford the most favorable soil possible for the growth of these micro-organisms; or, perhaps it is the same thing to say, have no power of resistance to their growth.

Multiple peripheral neuritis has been mentioned as the result of septicæmia. One well-marked case occurred under my observation in the person of a professional colleague who wounded himself in the hand at an operation for the opening of a phlegmonous cellulitis. The resulting inflammation was of decided severity, but not extreme, and after apparent recovery, having resumed practice, he experienced a gradual loss of power with pain along the nerve-trunks, first in the arm which had been the seat of the injury, but gradually invading both upper and lower extremities. It lasted nearly a month, and gradually disappeared, the recovery being complete.[1]

Gussenbaur's definition of septicæmia, which I have adopted, fixes no definite period of time for the termination of the disease, but the course as described is essentially acute. It is usually a matter of but a few days before death closes the scene or convalescence is established, or, pus forming, the subsequent course is claimed to transfer it into pyæmia of one form or another. It has seemed to me, however, that in a certain—and that not infrequent—number of cases the acute nervous symptoms subside and pus in moderate amount appears, the character and persistence of the febrile movement justify us in regarding the condition as chronic. It is a continuous fever, with about the diurnal variation that belongs to health, but is from one to two degrees higher. The temperature, instead of running along between 98° and 99° F., runs between 99° and 100° F. or 100° and 101° F., with, occasionally, a rise of a degree or a fraction of a degree more, but seldom falling below; not presenting the characteristic features of the pyæmic chart, of great diurnal vari-

[1] Consult Dr. J. J. Putnam: "Pathology and Etiology of Infectious Processes on the Nervous System," *Transactions of Third Triennial Congress of American Physicians and Surgeons*, vol. iii., 1894.

tions, but keeping the surgeon always anxious lest this should develop. This condition will sometimes last for weeks: every hospital surgeon must recognize the clinical description. I am unaware of any bacteriological observations having been made to establish the pathological condition behind it, but when we recognize that the occasional sudden accessions of temperature are always to be referred to some circumstance having to do with an increase in the production of the ptomaïnes of putrefaction, as by a remission of strict antiseptic treatment, intentional or otherwise, and that when this is re-established the temperature returns to its former, but still abnormally elevated, degree, until recovery is brought about by the curative processes of nature, the inference seems justified.

It may be urged that I am here giving another name to irritative fever. I prefer to give these cases a pathological rather than a purely theoretical classification.

The **prognosis** of septicæmia, like that of other acute infectious diseases, depends more upon the strength of the individual than upon anything else. There are two points, however, to be considered in this relation: the power of resistance of the tissues to the invasion of the micro-organisms, as shown by the rapidity of extension of the local process, and the amount of systemic disturbance which the individual suffers, as shown in the force and frequency of the heart's action. Single observations of temperature, even though high, are not of much importance in a prognostic point of view, but a continuously high fever has a bad outlook always. Age is an important factor, the very young and the aged withstanding the effects of septic fever and intoxication but poorly; and it goes without saying that any complication of septic infection occurring in persons already reduced by organic affection of an internal organ, be it kidneys, lungs, or heart, is of the gravest prognosis.

Other things being equal also, the prognosis is greatly influenced by the promptitude and thoroughness of the treatment. The inauguration of an active antiseptic treatment, though the temperature be very high, will usually be followed by a remission if undertaken before nervous symptoms become severe.

The **treatment** of septicæmia must have relation to prophylaxis as well as to the later manifestations shown in the general condition. In the early stages it is mainly local, and means the application of all the rules and remedies of the so-called antiseptic surgery of to-day; in the later period, when the heart threatens to give out, or the intestinal tract becomes irritable, or the brain is oppressed by the presence of a poison, the specific treatment of the disease, the antisepsis, becomes subordinate to that directed to overcoming these conditions of the general system. The prophylaxis of septicæmia, however, belongs to another subject; it is included in the treatment of all wounds, whether operative or otherwise; it has to do with the preparation of the patient for an operation—the operating-room, the instruments, dressings, the operating field, the personal cleanliness and disinfection of the surgeon and attendants of every grade, or, when these are not at hand as in a well-regulated hospital, to aim for them as far as possible, supplementing them, however, with remedies having in view the destruction of infectious substances which may have gained access to the wound before the care of the surgeon is

given it. It would, however, involve a repetition if these matters were given at length here; they will be treated of under the aseptic treatment of wounds. We have here to speak only of the treatment of wounds which have become infected: whether this be from the fault of the surgeon in not having achieved the desired asepsis, or from the nature of the accident and its surroundings, is indifferent; its existence is determined when the conditions heretofore described are found.

If the wound has become infected, the treatment is started antiseptically at once. The two principal methods are the dry and the moist. The first is founded on the well-known fact that the development of bacteria requires heat and moisture: if either of these be absent—*i. e.* if the temperature be near the freezing-point or if the parts be absolutely dry—no putrefaction can take place. The first of these conditions is, for obvious reasons, impossible of fulfilment, but the latter, if the wound be not very large or ragged, may be approximately, often sufficiently, achieved by the employment of materials of various kinds which will absorb the discharges of the wound and with that sterilize the soil in which the micro-organisms breed. Iodoform, boric acid, bismuth, indifferent substances, as starch, lycopodium, have this in common, and when freely applied with a thick sterilized dressing, as gauze, dried moss, jute, oakum, or even absorbent cotton, over them, will occasionally serve this purpose. The application of this method is, however, limited: it requires that the wound should be fairly smooth, with a minimum of ragged edges or exposure of surface, and that the secretion should not be very abundant: this occurs only in quite recent wounds.

When the wound is extensive, not capable of nearly complete closure, has a quantity of ragged edges and exposed muscles, with the intermuscular spaces and connective tissue leading along the vessel-sheaths laid bare, in every one of which the secretions of the wound collect and serve as fertile breeding-grounds for the bacteria, it is necessary that some means be employed either to remove them or to destroy the germs and their spores *in sitû*. For this purpose various antiseptic solutions are employed in many different methods to suit exigencies and to meet mechanical difficulties of situation, etc. There are three principal methods of applying the moist dressings: first, intermittent washing of more or less frequency; second, constant irrigation; third, application of dressings wrung out in various solutions or combinations of these solutions. Appreciating the importance of rest in every healing wound, as little disturbance as is consistent with the thorough removal of the infectious matter should be employed: we judge of the thoroughness of the removal by the effect on the temperature. The washing is done most conveniently with a so-called fountain syringe or irrigating bottle suspended above the level of the wound, to get the amount of force required to inject the washing fluid into all the interstices of the wound, using best a glass point for contact with the wound (in a hospital a separate point is kept for each patient), which in the intervals between use is kept in an antiseptic solution.

As warm water is usually more grateful to the patient's feelings than cold, it is in most cases best to use it; there are cases, however, when the putrefaction is active, in which the inhibiting effects of cold on the development of the micro-organisms may be tried with advantage, especially

if the bodily temperature be high, inasmuch as by reducing this we are restricting the activity of their reproduction. Having regard, then, to the temperature, the wound may be washed off with simply sterilized water; with a solution of carbolic acid from 1 to 5 per cent.; with mercuric bichloride of from 1 : 500 to 1 : 20,000; with potassium permanganate of from 1 to 10 per cent.; with hydrogen peroxide of from 1 : 1 or from that to 1 : 15; with Thiersch's solution [1]—according to the effect to be produced as shown by the odor and the degree of temperature. This is but a small list of the remedies recommended: they are, however, those in principal use, having stood the test of practical applications in many different hands and under various conditions. As to a choice between them, one is guided by idiosyncrasies of individuals and the effect on the tissues. Carbolic acid produces an unpleasant anæsthetic effect on the part if allowed to remain in contact with it long or if used in sufficient strength to be a germicide. Mercuric bichloride is the best germicide, but acts unfavorably upon the tissues themselves, and there is always the further danger of salivation if used freely. Potassium permanganate is expensive and stains everything with which it comes in contact, whereby the local process is hidden and one is at a loss to know what is going on in the wound; indeed, later investigations seem to show also that its *disinfectant* properties at least have been overrated. Hydrogen peroxide, which has been extensively advertised and lauded to an extent in some quarters that renders one suspicious, has very decided objections: it is expensive, is extremely uncertain in quality of manufacture, requires particular care for its preservation, and if used freely will salivate. For these reasons it is not adaptable for ordinary use. Taking it altogether, mercuric bichloride meets the indications for practical use the best, though it requires care about the sick-room in that there is nothing in its appearance or smell to distinguish a solution of it from water. Pharmacists have met the demand for its use by preparing tablets combined with ammonium (or sodium) chloride of definite strength, one of which, dissolved in a pint of water, makes a solution of 1 : 500, and with this as a standard the strength may be varied according to the indications. In order to identify the solution, tablets are occasionally colored with some indifferent coloring matter. In the hands of the laity this may be a wise precaution, but the solution is disagreeable to work with, to say the least.

In case of extensive laceration of skin and more or less exposure of underlying tissues, where a loss by slough is inevitable, and where, under ordinary circumstances, the sloughing process would surely be accompanied by a septic process of considerable if not dangerous intensity, where the practical indication is the application of a poultice to hasten the process of separation, my practice is to apply a thick layer of cotton or jute or mixed tissue freely wetted with a hot solution of mercuric bichloride of about 1 : 4000, covered with a rubber cloth or oiled silk to keep it from drying; this, which I call an antiseptic poultice, is changed every few hours (depending upon the urgency and the effect produced) by rinsing the dressing off by wringing it out once or twice with a fresh solution, and is again applied hot. By this means I am frequently able to treat an extensive sloughing process with little or no

[1] Salicylic acid, 2; boric acid, 12; boiling water, 1000: parts by weight.

febrile movement. A case in point occurred in a man the bottom of whose foot had been almost torn off in a "planer," the injury being very similar to the one above cited of *gangrène foudroyanté*, but in which I was able within a few hours to institute the treatment above described, and, although the suppurating process lasted several weeks, it was throughout its course absolutely odorless and afebrile. This extremely favorable course, however, is possible only when the treatment is instituted early, before the septic process has begun: it is really aseptic treatment, and not the treatment of septicæmia. It shows, however, what may be accomplished by that method of treatment, for frequently when the septic process is already in full swing the application of an antiseptic poultice as described will reduce the activity of the process or stop it altogether. If it does not, the dressing may be removed every two or three hours, the wound thoroughly washed out in every part of the interstices with a solution of 1 : 2000, and the poultice reapplied, carrying it well up to above the limit of the wound. In severe cases a more frequent change is required, and the solution should be allowed to drip constantly over the dressing, provision being made to carry it off: in aggravated cases a stream of the solution may be arranged to play constantly over the wound, at once disinfecting it and washing the loose and soluble products of decomposition away. This constant irrigation, however, requires caution, as it may salivate, and it should therefore not be used in greater strength than 1 : 10,000 for any length of time. I sometimes alternate the washing off of the wound with the solution once in two or three hours, with irrigation of sterilized water to wash away whatever sublimate may have remained on the surface or in the interstices of the tissues. Depending, hence, upon the temperature and the local swellings, the strength and the length of time of the application are to be judged, varying from intermittent washings of sterilized water to constant irrigation with a sublimate solution.

The entire submersion of an extremity in an antiseptic solution is practised in some cases when the laceration is extreme and the mechanical difficulties in the way of a thorough irrigation cannot be otherwise overcome. Following the practice first observed at the Massachusetts General Hospital, I have used the coal-tar product of sulphonaphthol in the proportions of from 1 to 5 per cent., the usual strength being 2 per cent. The limb is kept immersed in this solution for a few hours, the moist dressing substituted, and, if the temperature rises, the limb is reimmersed: I have used this quite satisfactorily in cases already septic when admitted to the hospital. The objection to it is a liability to produce dermatitis of the healthy skin above the seat of the injury, and a shininess of the surface where the moisture, which bears a certain resemblance to an emulsion, comes in contact with the raw surface. Patients, however, usually express themselves as relieved from pain in a short time. "Creolin" may be used in the same way.

Incisions through the skin into the swollen tissues to allow the escape of the infiltrated serum serve also as avenues through which the solution may be injected into the tissues where the products of putrefaction are developing: these incisions often require to be numerous and deep, and are frequently the means of saving a limb or life that otherwise would be sacrificed.

In septic lymphangitis and adenitis it is sometimes also necessary to issect out the contents of the axilla or groin, which have become foci rom which the septic process is further distributed. Unfortunately, owever, none of these precautions or remedies is sufficient to check the nward course of the disease: the phlegmonous process extends near id nearer the trunk; more and more of the limb becomes gangrenous; e fever becomes worse, the brain symptoms more pronounced; it is ident that unless the patient is relieved from the continued absorption the putrefactive products death will ensue. Under these circumstances e removal of the whole limb is an imperative necessity, and with it mes the decision of the seat of the amputation. Will it do to operate rough soft tissues already infiltrated with the products of decomposi-on, or must the whole limb be sacrificed, adding to the dangers of the peration, already very great? While such a thing is of course undesir-ble *per se*, and, other things being equal, is to be avoided, yet operation rough infiltrated tissues is not absolutely forbidden. It depends upon ne character and extent of the septic process. One cannot advise cutting rough a gangrenous tissue or one in the immediate neighborhood thereof, ut I have repeatedly, under stress of circumstances, amputated in regions here the tissues were infiltrated and discolored, and with care have had ecovery. I have in mind a man who was cut on the foot with an axe hich passed deeply between the great and second metatarsal bones with-ut injuring either, but in whom the wound became infected: gangrene ppeared in isolated spots on the leg above the ankle; the patient's gen-ral condition became exceedingly bad—could hardly be worse; pulse nd temperature both high, and, quite incapable of appreciating his ondition, he lay in a muttering delirium. The local appearances grew worse, the gangrenous spots appeared about the knee, and in desperation mputation was performed at about the junction of the middle and upper hirds of the leg as the highest point at which it was believed he would urvive the shock of operation. He was so torpid by the effect of the oison on his brain that he required almost no ether; he was unconscious f the operation for several days after it was over. The cut surface ardly bled; it was discolored and dirty with sanguineous serum; the rteries were occluded. *There was no odor to the freshly-cut surface or tump afterward.* There was no union by first intention, the skin-flaps ecame gangrenous along their edges, and yet the patient in time got well with a useful stump. This was an extreme case, and very doubtful n progress for a long time, but the end justified the risk; and, as less evere cases have also recovered, it can be claimed that while the practise s not desirable as a rule, it is sometimes good surgery.

An elevated position to the affected limb, if it be such, is most desira-ble, and the importance of rest in keeping the circulation as inactive as racticable is not to be forgotten; therefore the suspension of an arm r leg is to be practised if possible.

As to the treatment of the constitutional complications which occa-ionally arise, we are guided by general principles. The disease is from he beginning depressing, as shown in the heart's action; stimulants of ll kinds are therefore allowable, the choice being left to the taste of the ndividual (surgeon). The necessity and the amount required are indicated uite as much by the dryness or otherwise of the tongue as by anything

else, though the state of the pulse of course is to be considered. Brandy, St. Croix rum, Bourbon whiskey, in about the order mentioned, with the bitter tonics of cinchona and gentian, are the most desirable. If the patient can take milk, this in the form of milk-punch and egg-nog gives nourishment with the stimulation; if there be vomiting, "ginger ale," champagne, and carbonated water will frequently control it, and I have known fresh buttermilk to be retained when every other form of nourishment was rejected. Other forms of intestinal disturbance, as diarrhœa, are to be treated by the ordinary astringent and sedative remedies of acetate of lead, opium, catechu, tannin, etc. I have sometimes thought that good results in the beginning of an attack followed the administration of a brisk saline cathartic, which appears to relieve some of the toxic symptoms, and the opium is then better borne. When a diarrhœa occurs, it is best to stop the use of the mercuric bichloride and substitute something having less tendency toward intestinal irritation. If the diarrhœa becomes dysenteric in character, enemata of opium and starch and lead will frequently stop it. Great care must be taken in the nursing of patients in the severe cases, as the stupor is so great that the skin over prominent points becomes ulcerated, and bed-sores of great extent and obstinacy result. This is especially the case when the urine and fæces are discharged involuntarily. The patient should, if possible, lie upon an air- (or water-) bed, or, if that is unattainable, air-cushions and ring-pads, to take the pressure from the threatened points, and, above everything else, the most constant, unremitting attention must be given to keeping the patient clean and dry. Use frequent bathing with alcohol or cologne, dusting zinc powder or starch or lycopodium upon the parts afterward, and change the position from back to side and from side to side as much as the proper treatment of the local disease will permit. It must be remembered that the disease is most exhausting, and convalescence is correspondingly slow.

Pyæmia.

A secondary fever with certain constant characteristic diurnal features, coming on in the course of the healing of a wound by suppuration, has been known since the earliest medical writings. In the wars of the Middle Ages epidemics of such a fever attracted the attention of Ambrose Paré and of Paracelsus. The former noticed that fractures of the bones of the skull by sabre cuts, etc. were followed by abscesses of the liver; Paracelsus, that the fever was intermittent, commenced with a chill, and was frequently accompanied by inflammation of, and purulent deposits in, the joints. Morgagni described the abscesses as metastatic, and stated that the pus was carried to various internal organs —the lungs, liver, spleen, etc.—and there deposited from the blood-vessels; he described an exudation into the pleura also as the result of purulent absorption from a wound. The intermittent type of the fever and its epidemic character led to the opinion that it was of miasmatic origin. Modern research, however, especially Virchow's investigations on embolism and thrombosis, the experiments of Billroth and Otto Weber, and finally those of Robert Koch on the traumatic infective fevers, demonstrated that we have to do with the absorption of pus infected with micro-organ-

isms; and the definition of Gussenbaur is now regarded as correct—viz. pyæmia, or purulent fever, is "a general infective disease which arises from the entrance into the blood of the constituents of infected pus. It is distinguished from other septic infective diseases by the development of multiple abscesses in various organs, and by an intermittent fever."[1]

A pre-existing suppuration, which implies a process of several days' or weeks' duration as the source from which the infected pus is derived, is the almost constant rule in pyæmia, though there are exceptional cases in which the injury—not always an open wound, even—and the general infection run a simultaneous course, with the general symptoms of a septicæmia rather than those to be described as characterizing pyæmia, but where the autopsy discloses the presence of metastatic abscesses and purulent exudations. There are others, again, in which the original wound has healed, but the general disease has afterward occurred, running to a fatal termination, when the autopsy again shows multiple abscesses and purulent exudations in the serous cavities and joints.

Making the post-mortem appearances the diagnostic criterion, we learn that pyæmia may occur as either a primary or a secondary fever—that there may also be a period of incubation after the reception of the injury, with no general or local symptoms, during which the infection is, so to speak, working like an exanthematous fever, the general disease breaking out subsequently and running its course independently of the original injury. When venesection was a more frequent practice such cases occurred more often than they now do.

Pyæmia may run an acute or a chronic course, more frequently the former, death occurring in the course of from five to fifteen days; it may, however, last many months. It must be understood, at the same time, that the division is principally clinical; the pathology is the same—viz. the entrance into the blood of the elements of infected pus; and this differentiation has to do, first, with the amount taken up at any one time, and, second, with the power of the individual to withstand the infection. An attack of acute pyæmia may, though it is unusual, subside into a chronic course, and, *vice versâ*, one that has been pursuing a chronic course may quite unexpectedly become acute.

The course of a typical case of pyæmia is, in general, that at a variable period after suppuration has been established, the wound granulating and the discharge creamy, in all respects the wound pursuing a normal course, the patient has a chill—variable in intensity from a crawling along the back to the teeth chattering and the extremities shaking, in different cases also lasting variably from a few minutes to an hour or more. This is followed, sometimes accompanied, by an increase of temperature, which may rise two or three or even more degrees, falling to normal or below the next morning. This succession of chill and fever, with morning remission, may occur daily or every other day, and the likeness to malarial fever becomes marked. Along with the febrile movement there is a condition of general malaise—loss of appetite, thirst, and headache, with some sleeplessness; the patient is quite aware that he is not so well, and, if he be from or in a malarial district, will himself insist that he is suffering from malaria, the subjective symptoms are so identical. At the same time, or perhaps ante-

[1] *Op. cit.*, p. 158.

cedent to the febrile movement, the wound indicates that something has taken place to interfere with the healing process. The suppuration ceases; the granulations become pale and flabby, and may break down entirely, leaving the wound with a thin, dirty, sanious discharge; the edges of the wound become swollen and œdematous; frequently we are able to detect cord-like swellings along the course of the larger veins leading from the part: these are hard and tender to the touch, and may extend some distance up the limb toward the trunk. The limb will soon after swell in its whole extent, the prominences and depressions become obliterated, and the natural configuration of the limb quite lost.

The repetition of the chills and febrile movement continues with greater intensity, frequency, and irregularity; the alternations with subnormal temperature are more marked, falling sometimes to 95° F. or less, only to rise in a few hours to perhaps over 104° F. This great range, repeating itself for several days, irregular as to the time of day, is a striking feature found in almost no other condition. The patient emaciates rapidly, the thirst increases, the appetite fails, the tongue becomes red and dry, the skin, alternately bathed in sweat or abnormally dry, is apt to become yellowish in color, due not so much to interference with the function of the liver as to a change in the blood itself, the coloring matter being liberated (*hæmatogenous icterus*) by destruction of the red blood-corpuscles; the pulse increases in frequency and becomes weaker. In contradistinction to septicæmia, the mind is not often affected; instead of being apathetic and somnolent, the patient is conscious of his weakened condition, often wakeful, and annoyed by lights or sounds, and likely to be querulous and complaining. In cases which run a protracted course the breath frequently exhales a peculiar mawkishly sweet odor, compared sometimes to newly-mown hay, and the patient complains of a disagreeable taste always present. As the disease progresses secondary involvement of distant organs or parts becomes evident; the patient complains of pain in moving some particular and usually distant joints: it simulates rheumatism at first, and is frequently mistaken for that disease. The joint is tender on pressure or movement, red and swollen, but in the course of a few days fluctuation appears, and on puncturing or incising it pus is found: this condition may occur in several joints if the patient lives long enough. Other situations in the extremities—the subcutaneous connective tissue, the muscular interspaces, even the muscles themselves—are not infrequently the seat of the metastatic abscesses, and particular mention must be given to their occurrence in the medullary canals of the bones, where they may be undetected until they have made extensive ravages, or be only discovered at the autopsy. Their presence is to be suspected when the patient complains of severe pain in the bones with exquisite tenderness along the shafts: the slightest movement is agony. At first the tenderness is usually located at distinct points, afterward, however, extending over the whole bone. At first there is not much else than the pain, but later the tissues over the bone become œdematous, and, if the patient lives long enough unrelieved, other evidences of pus in redness and fluctuation become manifest, and by incision the involvement of the bone is shown in the loosening of the periosteum. Like the disease of the joints, the resemblance to rheumatism at the outset is considerable, in both the local and the constitutional symp-

tomatology; it is not until later that the true condition becomes locally manifest. It is therefore necessary to be keenly on the alert in the case of a suppurating wound to detect these evidences of transference to distant parts, because if the treatment be initiated early there is a chance of saving life or limb, which chance, however, grows rapidly less as the suppuration extends through the whole bone. In the beginning the abscesses, as in other situations, are single or isolated, but they increase in number and run together until the whole canal is occupied with pus.

Of other accessible organs, the secondary abscesses are to be looked for in the parotid and thyroid glands, and exceptionally in the testicle. Metastatic deposits in the internal organs often go undetected, their presence being, of course, by no means so evident as in the situations mentioned. Indeed, the special symptomatology of abscesses in internal organs—and they may occur in almost any—is not characteristic: in the lungs there may be cough and expectoration, with some dyspnœa, but so long as the abscesses are small there is little to judge from. With pleuritic exudation, however, the evidences of dyspnœa, with dulness on pressure, faintness or absence of respiration- and voice-sounds, indicate the condition; sometimes there are the other evidences of pleurisy—the inability to take a long breath, difficulty in lying upon one side or the other, and increase in frequency of the respiration.

Icterus is liable to be present in metastases into the liver, but, as this is also present as the result of the destruction of the red blood-corpuscles in hæmatogenic icterus, the condition is not diagnostic of the metastases unless it be associated with increased area of liver-dulness and localized tenderness, with possibly a tumor if the abscess become very large. In splenic involvement the increased area of dulness is almost the only sign to indicate the local trouble, and it is a further source of confusion if the question of malaria comes up. The spleen is, however, one of the rarer seats of secondary deposits.

The only case of secondary pyæmic abscess in the muscular tissue of the heart that I have any knowledge of I saw at the autopsy of an Italian laborer who died in the New Haven Hospital after an illness of nearly two months. This case will be referred to again in speaking of the mixed form of pyosepticæmia.

We have learned that a typical case of pyæmia consists clinically of —first, an open suppurating wound; second, a chill; third, a fever and sweat, these occurring irregularly; fourth, thrombosis; fifth, metastatic abscess; sixth, death in the course of two weeks; but, except the metastatic abscess or serous exudations, nothing is constant. As stated in the beginning, an open suppurating wound is not an absolute or constant feature. Wunderlich reports that a young working-woman suffering with an ordinary coryza wet her clothes during a hard day's work in which she perspired freely. The next morning, on getting up, she became faint and fell, injuring her right hand. Recovering consciousness, she was seized with a heavy chill which lasted some time; she had pain in her sternum, headache, vertigo, and diarrhœa. She died on the fourth day in collapse, having had a continuous high fever with erythematous bullæ on both feet. The autopsy showed a slight effusion of blood in the injured hand; the blebs on the feet were filled with hemorrhagic pus; the joints of both hands and feet were normal, as also the

tissue of the extremities, but there were multiple infarcts in the renal glands, the liver, and the kidneys, fresh extravasation in the brain, acute myocarditis, pericarditis, œdema of the lungs, and a softened spleen.

Greenhalgh reports the case of a physician who had a boil following the examination of carcinoma of the uterus which proved to be cancerous, and three weeks after he became ill with rigors on four occasions, double-sided empyema, and œdema of the lungs, from which he died on the fourteenth day. The autopsy revealed, besides the pleural manifestations, multiple abscesses in the lungs, a large abscess in the liver, and a softened spleen.

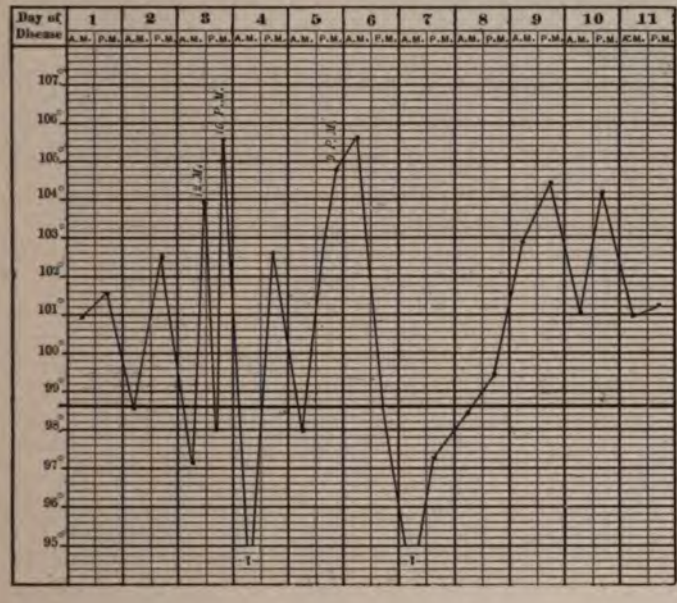
Although the chill is by far the most frequent manifestation of the proper pyæmic process, every surgeon who has much to do with the disease recognizes cases in which it is wanting, or first appears after the fever; and, further, while the repetition of the chill is the rule, it sometimes does not reappear at all. These variations, however, have no appreciable effect on the course of the disease nor on the termination. Billroth remarked, however, that disturbance of the wound was very apt to be followed by a chill: dressings of the wound, probing, and repetition of fragments of broken bones were followed by chills in the course of from two to six hours; it was remarkable how frequently the morning and evening visits of the surgeon were followed by chills.

While the type of pyæmic fever is the intermittent, this is not absolute. The "pyæmic curve" of the temperature chart has been spoken of as though it were something positive and pathognomonic, but it has just been shown that the fever may be continuous, the fact being that it depends largely upon the severity and rapidity of the infection as to whether this variation in the height of the fever is marked or not.

It also presents variations, even in its intermittence, which are to be noted, and which make the diagnosis doubtful if we depend upon the chart alone to determine it. The fever will sometimes rise by gradual steps, as between morning and evening, in the course of two or three days, to a considerable degree, 103° F. or over, then fall either as gradually or suddenly to normal, giving rise to the hope that the infection has been eliminated, only, however, to repeat the process of elevation. At another time in the same case the temperature will go suddenly up for a day, and in the next few hours fall again. Individual cases being liable to these striking variations from the type, little can be judged of a given case from the chart alone, except that great and repeated variations from subnormal to very high temperature after a suppurating wound indicate that infected pus has gained entrance into the circulation. As an instance of the great variations in the temperature occurring in a few hours, and also of the great irregularity in the course of the fever, take the accompanying chart of the course of an acute pyæmia in a child of about five years of age, paralyzed with a spina bifida, who was admitted with a great bed-sore alongside of and exposing the sacrum and coccyx. In spite of the utmost care after admission, it extended deeper, and after several months her temperature was one day found to be 101° F. in the morning, and she was feeling unwell. The child was too young to describe her sensations, and there was no objective evidence of a chill until later, but the variations in the temperature began at once, for on the second day it swung from $98\frac{6}{10}°$ to $102\frac{6}{10}°$ (4°), and on the third

day from $97\frac{2}{10}°$ to 104° between 5 A. M. and 12 M. ($6\frac{8}{10}°$); at 4 P. M. it had fallen to 98°, only to rise to $105\frac{6}{10}°$ at 10 P. M. ($7\frac{6}{10}°$), to fall the next morning, the fourth day of the attack, to *below* 95°. As the clinical thermometer was not graded *below* 95°, it was too low to register, but it

FIG. 13.



fell at least 11° in six hours: in the afternoon it rose to $102\frac{6}{10}°$ (8°). On the fifth day it oscillated between 98° and 103° at 4 P. M. to $104\frac{8}{10}°$ at 9 P. M., and the next *morning*, the sixth day, it was $105\frac{6}{10}°$, to fall in the afternoon (in opposition to the rule) to $98\frac{4}{10}°$, continuing to fall in the morning of the seventh day to be again *below* 95°; it only rose that afternoon to $97\frac{2}{10}°$. It continued to rise both morning and afternoon on the two succeeding days to $104\frac{4}{10}°$, and without further remarkably abnormal variations she died at the end of the eleventh day. At the autopsy it was found that the bed-sore had caused a necrosis of the sacrum—that pus had invaded the right sacro-iliac synchondrosis; there were numerous non-suppurating infarcts in the lungs, and in the left pleural cavity was a large amount of sero-purulent exudation.

Chronic pyæmia is characterized clinically by a fairly regular but excessive diurnal range in temperature, continuing for weeks or months; few or no striking exacerbations of this range are noted, but it varies from 98° F. or below to 102° or over almost daily. This condition, which has been described as hectic or irritable fever, is associated with slight and infrequent chills, with great loss of muscular vigor, emaciation, a red but not necessarily dry tongue; there is constant thirst. Usually the appetite is good, but the frequent attacks of diarrhœa and the emaciation show that the digestive tract does not assimilate the food taken; the anæmia becomes marked, the skin pale and even slightly

sallow or yellow. The intellect is clear, the sensibilities acute, but, owing to the extreme weakness, the patient remains in one position, sunken down in the bed, and bed-sores are liable to form: these appear especially in those who have diarrhœa, owing to the difficulty in keeping dry. The patient sweats both sleeping and waking, and trembles at the slightest exertion; even the effort of speaking exhausts, the voice trembles, and he weeps readily. The termination comes by exhaustion from the diarrhœa, or an exacerbation of the attack carries him off in a couple of days.

There are undoubted cases of infective fevers in which the symptoms are sufficiently marked to justify the opinion that products of decomposition in the wound and infected pus may be present at the same time, producing a septic pyæmia, or pyosepticæmia as one prefers to call it. The clinical course of such a condition is characterized by prominent symptoms of both diseases, and the autopsy reveals the presence of metastatic abscesses. An Italian laborer thirty-six years of age, who had been working in a sewer, was admitted to the New Haven Hospital on July 10th with a very incomplete history, but the distinct statement that he had had "chills and fever" for two weeks. He was assigned to the medical division and treated for malarial fever. On admission his temperature was 103° F., and under treatment it fell to 99$\frac{6}{10}$° in the evening of the second day. His countenance was dusky, and he was somnolent most of the time, or talking in his sleep and breathing irregularly, sometimes stertorously: his temperature rose again, however, and for the next three days it was irregularly between 99° and 101$\frac{6}{10}$° F. He had several loose movements of his bowels—was occasionally delirious, with twitching of muscles of face and tearing at the bed-clothes. He drank plentifully of milk; on July 14th a large abscess was found upon his right thigh and another on his right forearm: these were evacuated and found to contain 6 ounces and 1 ounce of pus, respectively. The mental condition remained about the same, and the temperature arose the next morning, July 15th; after opening the abscesses (which were washed with an antiseptic solution and drained) the temperature arose to 101.8° F. The temperature for the next thirteen days fluctuated daily from about 99° to 101$\frac{5}{10}$° F., on one occasion going up to 103$\frac{8}{10}$° F. At first his general condition improved and his appetite was good, but on the seventeenth day he refused his food, as it distressed his stomach, and he vomited occasionally. He got over this, and his general symptoms were more satisfactory again in that he ate and slept fairly well, with occasional lapses of his bowels, and his mental lethetude disappeared. On July 28th his temperature arose to 105° F., falling the next morning to 99$\frac{4}{10}$°, and on the 30th it arose to 103$\frac{8}{10}$°, to fall to 100.4°; and this was the last marked fluctuation, for the fever now became continuous, ranging for the next three days just across the 100° F. line, then for a couple of days at the 101° F. line; from this time, August 6th to 12th, it ranged across the 102° line, and on the evening of the 12th it arose to 105$\frac{4}{10}$° F. During this time his general condition failed: he became weaker, had from time to time vomiting and diarrhœa, with appetite in the intervals; there was no change in the condition of the abscesses on his thigh and arm, and no other development externally. On August 8th a yellowish color appeared on the

skin; on the 13th the temperature was lower, and continued to fall, until, on the morning of the 14th, it was at $99\frac{2}{10}$° F., as low as it had been for three weeks. He died the following day, the temperature having gone up to $106\frac{8}{10}$° at the last. The course of the disease was therefore about fifty days, but during all this time he was acutely sick. The autopsy showed the liver large, fatty, of a light color and pasty consistence; the spleen large, soft, and pulpy, with embolic infarctions. In the wall of the left ventricle of the heart (auriculo-ventricular valves) there was an abscess, the size of a walnut, which had opened into the ventricle. Both kidneys were enlarged, the left the most, with a great number of small abscesses interspersed through it; the right had a large abscess in the lower portion, with smaller ones in numberless quantity throughout the whole organ. Those in both kidneys were undoubtedly metastatic, and when one appreciates the abscess of the wall of the heart opening into the cavity of the left ventricle, pumping pus into the circulation with every pulsation, the source of the countless abscesses of the kidneys becomes evident. How long it had been doing this could not be determined from the symptoms. The urine was repeatedly examined, but beyond a "trace" of albumin showed nothing abnormal.

The **treatment** of pyæmia resolves itself, like that of other septic infectious processes, into local and constitutional, and the local into prophylactic and symptomatic; and of the latter it must be said our means of relief are very limited. What access can be had to multiple metastatic abscesses of the lungs, liver, or kidneys? The prophylaxis of pyæmia, however, is one of the greatest triumphs of modern surgery, if not the greatest. When Volkmann, at the International Congress of 1881 in London, stated that before the introduction of the antiseptic treatment of wounds the mortality in hospitals after major operations, from septic or pyæmic conditions, was from 80 to 85 per cent., and that since, if a case was lost from such causes, there was somewhere a surgical error, he said nothing that has not been abundantly confirmed by the experience of the surgeons of to-day. Pyæmia, which twenty-five years ago was the horror of military and hospital surgery, is now unknown—nay, impossible—as the result of operations in a well-ordered hospital or of a properly-conducted surgical procedure, and instead of hospitalism being the reproach of surgery, we now prefer to have our operations performed in hospitals, feeling more confidence that we can command the asepsis there than in other places. We meet pyæmia occasionally, it is true, but in cases that we do not have control of. It is as preventible as any other infectious disease. Knowing precisely the nature of the infectious elements and what will destroy them, knowing exactly from what point they gain access to the circulation, and in most cases having control over this process, it would seem that the surgeon's duty is fairly easy of fulfilment. The fact is, as above stated, that in operations where the wounds are from beginning to end under the control of a surgeon who appreciates the importance of asepsis and antisepsis, the disease does not occur. In these days we find it limited entirely to cases that do not come under proper surgical care until suppuration and infection are established; to cases of osteomyelitis in which the diagnosis is not made early or the proper treatment not instituted; following cases of phlegmonous erysipelas with extensive subcutaneous or

subfascial suppuration, and similar conditions of septic infection which have withstood the action of the micro-organisms of decomposition, but have left a field in which the resistance to purulent infection is of the slightest.

The treatment of the preliminary conditions leading up to pyæmia consists of the most rigid antisepsis. Frequent dressings for the removal of pus, washing of the wounds with solutions of mercuric bichloride or other of the antiseptic or disinfectant remedies that have been referred to under the treatment of septicæmia, laying open freely pockets or sinuses of pus, making the position of the part such as to allow free exit of all drainage,—are matters of great importance, as also the sterilization by heat or otherwise of all bandages and dressings, and the most thorough surgical cleanliness, especially in avoiding any possible contact with other suppurating wounds, and of the instruments or utensils or other apparatus used upon them without intermediate disinfection. In some hospitals separate wards are provided for the suppurating and non-suppurating cases, so rigorous is the warfare against contagion: in lying-in hospitals it is the rule that septic cases are at once to be isolated.

If the metastatic abscesses are within reach, they are to be treated as abscesses everywhere, and as energetically as possible: in the subcutaneous or subfascial planes they should be as freely opened as is necessary to obtain and maintain complete evacuation of the pus, and then be disinfected as actively as possible. Much knowledge may be gained of the formation of these abscesses, and the necessity of looking for them, by carefully watching the temperature. In a case presenting distinct pyæmic features following a phlegmonous erysipelas I was able, by judicious observation on the part of the nurse as to chills and the following rise in temperature, to diagnosticate some twenty to twenty-five small abscesses, one after the other, in the subcutaneous tissue, which would otherwise have escaped observation until they had obtained a large size or had served as secondary foci. The certainty that the chill was the evidence of a fresh deposit of pus was the incentive to more careful searching, and in almost no instance were we deceived, and the patient recovered from a condition that seemed at times hopeless. Suppurating joints are to be freely incised and carefully washed out; if the suppuration has spread into the neighboring tissues, amputation is to be considered, and has been performed with the result of saving life otherwise doomed. Similar advice should be rendered in cases of pyæmic osteomyelitis, with even more insistence than with joints, for the medulla is a lymph-channel, and, being hidden, is just so far a more dangerous situation from which the infected pus may be spread. It is a matter of saving life rather than of conservative surgery.

When thrombosis occurs, with the possible sequence of embolic metastasis of the infected clot, the proposition has been made to in some way check the current of the circulation between the thrombosis and the heart, and in this way to prevent the wider distribution of the disease. Compression, isolation, and ligation of the vein have from time to time been employed, and in some cases with success. These are, however, unusual cases, and the practice has not become general: the fact that all thromboses do not lead to emboli, that a fairly large number get

well, makes it incumbent on the surgeon to hesitate before undertaking an operation that might possibly hasten the very process it is intended to check, but instead to try, by warm, moist antiseptic applications, suspension or elevation of the limb, and complete rest, to obtain regression.

Besides the local treatment, the general condition of the patient demands attention: the indications are to support the patient by stimulants and tonics and to nourish by food. Milk-punch and egg-nog made up with St. Croix rum or brandy fulfil the therapeutic indications. Cinchona is also frequently of benefit—whether the bark or its alkaloid is not of especial importance, except for the smaller dosage of the latter. Too much stress cannot be placed on the absolute necessity of an abundance of fresh air in the treatment of pyæmia and septicæmia.

Poisoned Wounds.

In poisoned wounds there is introduced at the reception of the injury some substance having a deleterious influence either upon the tissues at the point of entrance or on the general system, or on both, it being distributed to the general system through the circulation, the deleterious result being out of all proportion to the injury received.

The influence is something more than that of a foreign body which excites local action in attempts to get rid of it, and if prolonged gives rise to fever. It is different from the morbific action of the toxines of septicæmia induced by micro-organisms of various kinds. It is different, again, from wounds in which the diseased secretions of animals are introduced into the circulation, giving rise to the phenomena of disease at a later day, as hydrophobia. It is the direct action of the substance itself upon the tissues (using the term in its largest sense) with which it is brought in contact, and the effect produced depends, in a given case, entirely upon the amount introduced into the circulation.

The poisons are both vegetable and animal: the former are usually introduced on weapons of warfare by the natives of the islands of the Indian Archipelago and of South America; the latter, by certain insects and reptiles.

In the East Indian islands the poison is procured from incisions made in the bark of the upas tree, of which there are two species, the *Upas antiar* and the *Upas tieute*, the poison of the latter being the more active of the two. Fabulous tales have been reported of the effect of poisonous exhalations from these trees; these are now known to be untrue. There exudes from the incision a gum-resin, which is poisonous taken internally or introduced into the circulation. The arrow- or lance-points are smeared with this resin, and the effects of the poison are great prostration, a feeble irregular pulse, vomiting, involuntary evacuations, convulsions, and death from cardiac paralysis.

I am unaware of any direct antidote to this poison, or indeed of any investigations looking to that end, but, judging from the symptoms as detailed, the indications are for active stimulation, alcoholic and diffusible.

The South American Indians use a poison variously named woorari, urari, or curare, which is obtained from various species of Strychnos growing in the Amazon and Oronoco regions and in British Guiana.

An extract is made from the bark and leaves, and in this the points of the arrows are dipped. It is very powerful; a small quantity introduced into the circulation acts by paralyzing the motor nerves, shown first in a feeling of weariness and disinclination to move, followed rapidly by complete paralysis of all muscles, including those of respiration, by which death comes, the heart acting after the respiration has ceased. In larger doses the vagus nerve and heart become paralyzed. The action is quite rapid, death occurring in a few minutes with fatal dosage. If the amount introduced be not sufficient to kill at once, life may be saved by keeping up artificial respiration until the poison be eliminated by the kidneys, which occurs fairly rapidly.

There is no evidence that the North American Indians have ever used poisoned arrows as such. The traditions to that end are based on certain rites with which they intersperse their war-dances preparatory to a foray. They mix up a lot of stuff in which putrefying animal matter obtained from snakes and other reptiles enters largely; in this they dip the points of their arrows, using various incantations of a semi-religious kind, in order that the arrows may be more potent against their enemies. This mess of course contains a great number of microbes of decomposition, which, entering the tissues at the wound, may produce septicæmia, and be so far poisonous; beyond this there is nothing.

Animal poisons are introduced either as stings or as bites. Stings are usually made by insects carrying the weapon at the posterior extremity of the body, the venom being secreted by a gland, and emptied into the wound at the time of puncture by the sting, which is usually barbed or serrated along its edges. The sting is really an ovipositor, consequently only females sting. Exceptions to this are found in certain gnats and bugs, of which the common mosquito and bed-bug are familiar examples: these sting by a proboscis, and both sexes are venomous, as is also the case with biting insects, of which the spider is the most common.

The venomous sting-carrying insects with which the physician has principally to do are wasps, hornets, bees, and some species of scorpions. This by no means exhausts the list of poisonous insects, and there are some venomous flies, but they are rare. Care must be taken, however, to differentiate between venomous flies and those which serve simply as carriers of infective material. There are no known scavengers comparable to the common house-fly: frequenting and living upon decomposing animal matter, it may, and frequently does, carry the microbes of putrefaction and of infection to minute wounds, and thereby excite a septic process which kills.

The action of the venom upon the human subject is similar in all. A local irritation of varying intensity is excited, depending upon the amount of poison injected. If there be enough of it, constitutional symptoms are excited, but there are great differences in individuals as to the amount required to produce such effects. It is also well established that persons may become in time immune to the action of the poison by repeated stings: this is the experience of most people living continuously in mosquito-infested localities, and with those who work among bees the effect becomes less and less with successive doses of the poison, so that finally in each case the sting excites no more action than the simple puncture.

Usually the sting produces much more pain than can be ascribed

he puncture alone, lasting some hours. In a very short time, a minutes, after the puncture an area of redness surrounds the point, h also rapidly becomes œdematous: with the appearance of the na the centre becomes white, and there is then a swollen, red areola a white spot in the centre, which itches and burns. It is evident that ction of the poison is first to produce a paralysis of the vasomotor es, allowing the dilatation of the blood-vessels for a considerable around the puncture, but whether the white spot in the centre be to a cutting off of the circulation by the swelling around it (Van n), or to a constriction of the vessels themselves by the action of the n emptying them of blood, may be a question; but, taking into con- ation the fact that in severe cases there is a slough at the centre, I lisposed to regard the white centre as the immediate effect of the n. Not infrequently the sting itself is broken off and remains in vound: this occurs if, as is usually the case, the insect is knocked at the moment of stinging; if, however, it be not disturbed, the on is withdrawn entire. Where the sting remains there is the ad- nal irritation consequent to the presence of the foreign body. Not quently there is vesication over the reddened area, and in a consid- e number of cases the redness and swelling and irritation extend ips over the whole extremity, with considerable pain lasting for al days, even weeks, and a feeling of numbness with anæsthesia and ess in movement, showing that the nerve-trunks are affected in both sensory and motor filaments. Usually a sting or two or three do roduce an effect upon the general system, but if there be a large er the constitutional effect may be great. Death has followed in a inutes after the attack of a swarm of bees which had been disturbed. symptoms are referable to the heart and lungs: the pulse is feeble irregular, the respiration hurried, superficial, and gasping, the tenance livid, the skin clammy; there are great prostration and able collapse, in which condition the patient dies. Additional er exists when the stings are in the vicinity of the air-passages the swelling interfering with the respiration, death having taken from œdema of the glottis producing suffocation. Wounds in nouth occur sometimes in eating fresh honey in the comb or in g fresh fruit picked up from the ground with the insects upon it.

he **treatment** of the local irritation, after removing the sting, sts in cold applications, with ammoniacal water if agreeable. The ations for general treatment depend a little on how the heart is g: if that be fairly strong, anodynes may be given to allay the and irritation, but if it be feeble, both alcoholic and diffusible lants must be used; besides the usual forms of alcohol or brandy, key, etc., the preparations of ammonia, carbonate or muriate, and hor, may be exhibited, together with hypodermic injections of alis, nitro-glycerin, and strychnia.

Many varieties of spiders are venomous, the tarantula being perhaps most so, but scorpions, galeodes, centipedes, are all more or less erous. The effect of their bites is in the main similar to that of s, as just described, but they are apt to be more severe, leaving their s upon the nerve-trunks much longer. These animals are usually nd keep themselves hidden until disturbed, and then rush out from

unexpected places, retreating again to their hiding-places. The tarantula, however, must be regarded as an exception, as it is liable to be quite pugnacious, attacking animals much larger than itself most vigorously. The hiding-places are oftentimes quite unexpected, as appears from an account in the *Australian Medical Gazette* for June, 1894, in which three cases of spider-bites upon the penis are detailed, the nesting-place of the animal being under the seat of an out-of-doors privy closet. All the cases occurred in the month of March, and in each case the examination of the locality revealed a brood of spiders of the genus Lathrodectus, consisting of a mother with from twenty to thirty young ones; and Dr. Parry, who reports the cases, suggests that they are venomous only during the breeding season: it is probable that they are simply more easily excited to attack at this time, owing to the maternal instinct. In these cases, besides the usual local effects of a burning pain and swelling, the remote effects on the nervous system were shown by the occurrence in the course of a couple of hours after the injury of an exceedingly disagreeable pain, as of pins pricking him, in the patient's toes: this gradually spread up to his ankles and knees; the part became bathed in a cold perspiration. The temperature was slightly subnormal and the heart's action feeble. The pain continued for forty-eight hours, and the perspiration, confined at first to the lower extremities, became general, and so profuse as to soak through the blankets on the bed. It gave off a peculiar, very offensive cadaverous odor. The patient was exceedingly restless, unable to sleep without anodynes, and suffered pain all the time. He was confined to his room for five days, but for two weeks there were darting pains through his legs and around the lower part of his abdomen. Dr. Parry regards the lesion as that of a peripheral neuritis.

Of poisonous serpents there are four genera in this country—viz. of the rattlesnake there are two, the *Crotalus*, with fourteen distinct species, and the *Caudisona*, with four; the copperheads and moccasins are of one genus, the *Aricistrodon*, divided into four species; the vipers *Elaps* are of five species.

The first three genera above mentioned have movable poison-fangs situated in the upper jaw, which ordinarily, and always when the mouth is closed, lie folded back and are concealed behind the upper lips, but which on opening the mouth widely are capable of becoming erect. The viper has small permanently-erect poison-fangs, situated farther back in the jaw than in the Crotalidæ.

In Europe the viper, *Pelias berus*, is the only venomous serpent met with, and, as compared with those of America and India, it is almost harmless; deaths from viper-bites are extremely rare in Europe.

It is in India, however, that the venomous snakes are met with in the greatest number, variety, and virulence, the mortality from snake-bites being very great. According to Sir Joseph Fayrer, the deaths from snake-bites alone are about 1 : 10,000 of all deaths. The principal genera are the cobra *Naja*, or hooded snake, the krait *Bungarus*, the ophiophagus and the daboia. The first named is the most venomous known and the most frequently met with: nearly one-fourth of the deaths from serpent-bites are caused by the cobra. Next in frequency are the krait, then ophiophagus, a large and very ferocious snake, having the habit of

devouring other snakes, hence the name; the daboia is of the viper genus and most venomous of its race. There are many other genera, but they are relatively unimportant, except as showing the great numbers in that country. The true Hydrophidea (water-snakes or sea-serpents) are found principally in the neighborhood of the islands of the Indian and Pacific Oceans and of the seas between China and Australia. They are exceedingly venomous and somewhat aggressive, but not large, usually less than five feet in length.

The mechanism of the poison apparatus is essentially the same in all. The venom-gland, analogous to the parotid, is situated upon the superior maxilla below and behind the eye; it is a flattened oval in shape, tapering forward to a duct leading to the base of the fang in front. There is no especial sac or reservoir for the collection of the venom, but as the duct runs through the centre of the gland it dilates a trifle, and in this there is a small store of venom collected. The fang itself is not, as is commonly supposed, movable at its attachment to the jaw, but that portion of the maxilla with the fang inserted in its socket is attached loosely to the rest of the bone, and on dilating the mouth widely this portion of the jaw turns in such a way as to bring the point of the fang to project downward and a little backward; with the closure of the jaws, the fangs being erect, they are driven into the skin if it be an animal: the temporal muscles press upon the gland and squeeze the poison out into the duct and along the groove in the posterior edge of the fang, and it is thus led to and injected into the tissues of the animal attacked. The fang itself is very sharp, sickle-shaped, with the concavity backward. The erection of the fang is a voluntary act in itself, not the effect simply of opening the jaws widely; the mechanism is quite complex, but it is unnecessary to describe it here. In feeding the fangs are not erected, but are kept folded back and covered by a sheath of mucous membrane. The poison is ejected with considerable force, sufficient when it misses its mark to throw it five or six feet away.

In the vipers the fangs are permanently fixed, and are situated farther back in the jaw than in the serpents above described; they are not so long or curved, and the groove is not so deep. The gland is not so large, either; the jaws cannot be opened so widely, and the muscles do not act with so much force. Taking it altogether, it is a much less effective mechanism, and in consequence vipers are not nearly as poisonous.

The effect of the injection of the venom is a "swelling at that point, with intense violet-black discoloration of the skin, which gradually extends over an area of several square inches. The tissues in the immediate neighborhood are soaked with extravasated blood. If death occurs soon, local extravasation may be all that is visible, but if it be postponed for a short time, then smaller extravasations are found in distant tissues. Most frequent and most pronounced are subpleural, subperitoneal, and subpericardial ecchymoses, but the whole organism is deeply affected, the tissues being congested and presenting a much darker appearance than normal. The blood does not seem to coagulate readily within cavities or interstices of the body unless death follows almost instantaneously. In cases which live longer the blood remains constantly in a liquid state or coagulates imperfectly, and then only after being

exposed to the air, resembling in this particular the state of that fluid observed in conditions of asphyxia."[1]

The symptomatology is similar for the different genera, the differences being due to the amount of venom injected and individual susceptibility. Besides the points just given, the whole limb swells, ecchymoses appear under the skin and sanious vesicles upon the surface, and if the patient lives the skin directly about the wound becomes gangrenous. The constitutional symptoms are of great severity and rapidity: the pulse is feeble and fluttering; at first nausea and looseness of the bowels may occur, followed by involuntary evacuations of urine and fæces; there is great difficulty in breathing, with pain about the præcordia; at first there are great anxiety and restlessness, but as the effect of the poison extends to the nervous system the sufferer becomes delirious, then indifferent, then somnolent, and dies in a state of coma. The time of death varies from a few minutes to several hours after the bite.

In non-fatal cases there is considerable variety in the symptoms, and cases are reported of singular delay in their appearance. Thus, Dr. Yarrow[2] states that constitutional symptoms were not present until four days had passed, the local symptoms also being simply troublesome; but with the coming on of the constitutional symptoms the local became more active, simulating phlegmonous erysipelas. The patient continued to grow worse for twelve days, when under treatment the disease took a favorable turn, and he eventually, in the course of about four months, recovered. In other cases, again, there are recurrent symptoms, coming on after intervals of varying length; nor are the symptoms themselves constant. Dr. Piffard of New York reports a case where a vesicular eruption appeared at varying intervals of from three months to a year in a young woman whom he first saw six years after the bite. Dr. Coleman reports a scaly eruption resembling ichthyosis coming on in two successive years after a venomous snake-bite (variety not given), and Dr. Yarrow's case had marked constitutional symptoms at about the anniversary of the bite, with a good deal of local reaction: he reports two other cases having similar experiences. The evidence of these recurrences comes from too reliable observers to be ignored. It is difficult to explain them, but that they have to do with a neurosis is quite evident.

The evidence that the *Heloderma suspectum* (the "Gila monster"), a lizard found in Northern Mexico and the South-western United States, is poisonous is too conflicting to allow a positive expression of opinion, the latest experiments by Dr. Yarrow being altogether negative, though most careful observers have thought it is poisonous, the grooved fangs indicating poisonous qualities.

The treatment of venomous snake-bites, to be efficacious, requires to be of the most energetic character. The first aim is to prevent the poison from getting into the general circulation, or to have it enter in such small quantity and so slowly that it shall not act powerfully on the nervous system—that its action be delayed. Therefore tie a ligature as tightly above the bitten part as possible to be borne: the larger the

[1] Mitchell and Reichert: "Researches on the Venom of the Rattlesnake," *Smithsonian Contributions to Knowledge*, No. 647, p. 139.

[2] *Amer. Jour. of Med. Sciences*, April, 1884, p. 422.

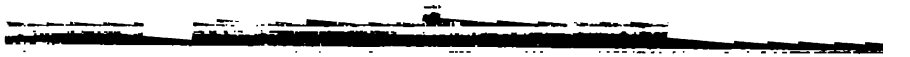
limb—*i. e.* the nearer the body—the more difficulty there will be in doing this. Then the part may be sucked (with sound lips), but, better yet, let it be excised freely and deeply, the sucking applied afterward, and bleeding facilitated. I can see no good to be accomplished by cauterizing: the wound is too small to be followed into its recesses by any caustic liquid or solid, and nothing is gained by cauterizing the skin over and around it. The ligature should be kept on if the patient can bear it, even after constitutional symptoms have become severe, as it must delay the rapidity of the entrance of the poison into the general circulation. The indications for constitutional treatment are active diffusible and alcoholic stimulants. Aromatic spirits of ammonia, whiskey, brandy, camphor, etc. are in order, but the overwhelming of the system with whiskey or alcohol, in obedience to the popular fallacy that to get a man drunk will cure him, has undoubtedly cost many lives from the whiskey. Patients are usually greatly excited, and therefore can tolerate large quantities of stimulants without intoxication, but if a man be intoxicated he is in a less favorable condition to eliminate the poison. So long as the heart's action is feeble and the pulse intermittent, stimulants and digitalis and strychnine, with perhaps nitro-glycerin, may be given freely.

The cautious statement of Drs. Mitchell and Reichert that "potassic permanganate, ferric chloride in the form of the liquor or tincture, and tincture of iodine seem to be the most active and promising of the generally available local antidotes," is sufficient answer to the vaunted claims of all sorts of nostrums as antidotes.

Death comes, according to the observations of these most capable observers, "through paralysis of the respiratory centres, paralysis of the heart, hemorrhages in the medulla, or possibly through the inability of the profoundly altered red corpuscles to perform their functions. There can be no question, however, that the respiratory centres are the parts of the system most vulnerable to venom, and that death is commonly due to their paralysis."[1] "The outlook, then, for an antidote for venom which may be available after the absorption of the poison lies clearly in the direction of a physiological antagonist, or, in other words, of a substance which will oppose the action of the venom on the most vulnerable parts of the system. The activities of the venoms are, however, manifested in such divers ways, and so profoundly and rapidly, that it does not seem probable that we shall ever discover an agent which shall be capable at the same time of acting efficiently in counteracting all the terrible energies of these poisons."[2]

[1] *Amer. Jour. of Med. Sciences*, April, 1884, p. 156.

[2] *Ibid.*, p. 157.



TRAUMATIC FEVER, ERYSIPELAS, AND TETANUS.

By J. COLLINS WARREN, M. D.

I. Traumatic Fever.

The constitutional disturbance which occurs during the healing of a wound is known as traumatic fever.

Traumatic fever may be divided into two principal varieties—primary wound-fever and secondary wound-fever.

Primary wound-fever may be also subdivided into two varieties—aseptic fever and septic or surgical fever.

Aseptic fever is a febrile disturbance which occurs in wound-healing by first intention. In this form of healing the symptoms of local inflammation are absent, and it was supposed in the early days of antiseptic surgery that such wounds would not be accompanied by fever. It was found, however, that the fever-curve often rose to a considerable height. In this respect the conditions differ from those seen in surgical fever, where the constitutional disturbance keeps pace with the varying conditions of the inflammation in the wound.

The cause of this rise of temperature was at first not fully understood, but experiments on animals have shown that the absorption of fibrin-ferment is often accompanied by serious symptoms. Fibrin is formed by the union of two fibrin-generators, fibrinogen and paraglobulin, with the co-operation of fibrin-ferment. Fibrinogen is found in the blood-plasma, while the fibrin-ferment and the paraglobulin are for the most part found in the white blood-corpuscles. If the fibrin-ferment is introduced experimentally into the circulation, extensive coagulation of the blood will be the result, and the death of the animal speedily ensues.

During the process of healing by first intention a certain amount of fibrin-ferment is absorbed from the extravasated blood, and also other substances which are found in the exudation which accompanies the inflammatory process.

In a large wound healing by first intention we find not only extravasated blood and exuded serum, but minute fragments of tissue which have been separated from the surface of the wound during the operation, and are subsequently disintegrated and absorbed. These materials when absorbed exert a pyrogenic action upon the system. Their close relationship to living substances, however, renders them but slightly injurious, and they produce in consequence only a mild type of fever.

The **symptoms** of *aseptic fever* are few in number. The patient experiences no sense of discomfort, such as is observed in other forms of fever. The skin is not so hot or dry, the urine is not diminished, and there is far less loss of weight than in septic fever. The thermometer, however, shows that there is a rise of temperature of from one to three degrees, and there is also a corresponding increase in the pulse-rate, which continues so long as any absorption is taking place from the interior of the wound. The patient is, however, unconscious of fever, and is often able to move about the room without discomfort. This form of fever lasts usually from one to five days, or may continue longer when hemorrhage has taken place and a considerable amount of blood has to be absorbed. Fever of this type is seen in cases of simple fracture and in large wounds healing by first intention, in cases of hæmatoma, and in contused wounds where there has been considerable hemorrhage.

Septic or *surgical fever* is observed in wounds healing with more or less septic inflammation, such as are seen following accidents or in cases where the principles of antiseptic surgery have not been observed. In such cases, although the wound may unite in the larger part of its extent, there is a great amount of redness and swelling and the other symptoms of local inflammation. A considerable discharge will take place from any open point in the wound, and perhaps also from the openings around the stitches, and in a few days a more or less extensive suppuration may take place, although in fortunate cases a great portion of the wound may be healed before the formation of pus has taken place. These active changes in the wound were formerly supposed to be symptoms of the brisk reaction in the wound, and were thought essential to the process of repair. We now know that they are due to sepsis. The constitutional symptoms are correspondingly severe in these cases, and keep pace pretty accurately with the amount of inflammation which occurs in the wound.

As an ordinary result of an operation or accident there is a certain amount of shock, the temperature falls below the normal, the skin is cold and clammy, and the pulse weak. The following day reaction occurs: the pulse and temperature rise, the skin becomes hot and dry, the tongue coated, and the patient suffers from considerable thirst and restlessness. On the evening of the second day the temperature is still higher; there is great discomfort, and the patient may also suffer from pain owing to the swelling of the wound. On this account sleep is difficult; the patient may not only suffer from insomnia, but nervous symptoms will be present, and in severe cases often delirium. The temperature drops slightly every morning, to rise still higher in the evening. With the subsidence of the local inflammation the temperature also falls, and with the discharge of pus from the wound the fall may be quite rapid, and there will be at the same time relief to all the other symptoms of inflammation.

Traumatic fever usually lasts about a week, at which time, if no extensive suppuration has occurred, the temperature will be found to have reached the normal line.

The **cause** of this form of fever is found to be the presence of bacteria in the retained secretions of the wound. A limited number of micro-organisms find their way into the circulation from this source.

The decomposition which they have set up in the retained fluid liberates a certain number of chemical substances which are also absorbed. The ptomaïnes and toxines thus introduced into the circulation exert a pyrogenetic action. It is probable that no one form of virus habitually causes traumatic fever, but that various substances have this effect. Fortunately, they do not exert a very poisonous action upon the tissues, but sufficient to cause considerable fever and discomfort to the patient. With the advent of suppuration these substances and organisms are carried away in the discharge from the wound, and, as those which have already obtained an entrance into the circulation are speedily eliminated, the fever then disappears.

Secondary wound-fever, or suppurative fever, occurs when pus has formed which has not an opportunity to escape from the wound, and in consequence chemical substances formed in the pus by the bacteria are absorbed into the system. In this case the fever-curve, instead of falling to the normal line at the end of the first week of the healing process, rises again, and this rise in some cases may be accompanied by a chill. There is usually a marked morning remission, with a subsequent rise of temperature every evening, which becomes more exaggerated as the suppurative process extends. Marked types of this form of fever are seen in the suppuration which follows compound fractures and in operative wounds in which the flow of pus has been obstructed. The pus consequently burrows in the surrounding connective tissue. In these cases the symptoms which accompany the rise of temperature are similar to those which we have just described. The patient suffers from dryness of the skin and coated tongue, headache, malaise, and in severe cases a mild delirium. When a free evacuation of the pus has been obtained the symptoms disappear and the temperature falls to the normal line. In unfavorable cases, where the pus has burrowed in various directions, chronic suppuration is established, and the fever now resumes the characteristic remittent type. In the morning the temperature is normal or even subnormal, but in the evening there is a sharp rise, varying from one to six degrees. Unless the progress of the suppuration is checked there is a marked change in the appearance of the patient. The loss of flesh is often very great, prostration occurs with the evening rise of temperature, the characteristic hectic flush is established, and with the fall during the night there is the profuse perspiration or night-sweat which is so characteristic of this condition. Diarrhœa may also set in to aggravate the patient's condition. In fatal cases emaciation becomes extreme, the joints are unusually prominent, and bed-sores appear. The patient finally becomes exhausted and succumbs to the disease.

The principal change found at the post-mortem examination is amyloid degeneration, which occurs in the spleen, liver, intestines, and kidneys. This is supposed to be caused by the constant presence of alkaline salts produced by suppuration. This type of fever has been sometimes confounded with pyæmia, and is called by some authors pyæmia simplex, in contrast with the multiple or metastatic form of pyæmia. It should not, however, be confounded with this affection.

Treatment.—Aseptic fever usually requires little or no interference on the part of the surgeon. Persistence in the rise of temperature indicates the presence of an unusual amount of blood collected beneath the

lips of the wound. In such cases the healing process may be hastened by the introduction of the probe or of a temporary drain to allow the escape of the blood-serum, which prevents the accurate coaptation of the surfaces of the wound. In surgical fever a careful watch must be kept as to the condition of the wound, in order that, if suppuration is established, provision may be made for the proper evacuation of pus. The removal of one or more stitches or the introduction of the drainage-tube may be sufficient for this purpose. If, however, the general appearance of the wound is threatening, it should be freely opened, a thorough disinfection of its surfaces should be effected, and provision made for the free discharge of the products of decomposition.

When it is clear that suppurative fever is established, the pus which is causing this disturbance should be followed relentlessly in all directions. In localized collections of pus a moderate opening is often sufficient to check the further progress of suppuration, but when pus begins to burrow free incision should be made and the walls of the wound should be curetted, so as to remove, if possible, all pyogenic organisms. When it is impossible to lay open the wound in its entire extent, a counter-opening should be made at some prominent point, through which drainage-tubes leading in various directions may be introduced. The wound should be thoroughly flushed with some antiseptic agent sufficiently weak to avoid poisoning by absorption. For this purpose carbolic acid in the strength of 1 : 200 may be used, or corrosive sublimate in a solution of the strength of 1 : 5000. The penetrating power of the corrosive is not so great in this case as that of carbolic acid, as the latter is able to incorporate itself more completely with greasy substances. Sulpho-naphthol, in a strength of 1 : 250, or creolin may be used. The disinfection of suppurating wounds may also be effectually accomplished by the application of peroxide of hydrogen.

The drainage may consist of rubber tubing or of strands of iodoform or sterilized gauze.

The strength of the patient should be carefully watched. Alcoholic stimulation is of great importance in these cases. The patient will often be able to bear a large amount of alcohol without discomfort. Good hygienic surroundings should be secured, and the patient may often be placed in the open air for many hours at a time, even in cold weather, with benefit during the process of chronic suppuration.

II. Erysipelas.

Erysipelas is an acute inflammation of the skin spreading along its upper layers and occasionally penetrating to the deeper tissues. It may involve mucous membranes. It is accompanied by fever. It has a tendency to more or less complete recovery, but it may recur. The name is derived from ἐρυθρός, red, and πέλλα, skin.

Although the disease was known to the ancients, reliable reports previous to the epidemic described in France in 1750 are rare. Epidemics are described as occurring in Great Britain in 1777 and 1780, and also in 1821 and 1832. A very extensive epidemic of erysipelas occurred in this country in 1842, and the disease is described as prevailing in various parts of Europe in the following year. The accounts of this last

epidemic are clear, and show the disease to have existed in a far more malignant type than that seen to-day. In fact, epidemics of this disease are at the present time practically unknown in civilized communities. The disease often assumed at that time the phlegmonous type, and worked its way deeply between the muscles of the trunk, and sometimes involved a whole extremity. In New England it spread from village to village and many lives were sacrificed.

The streptococcus of erysipelas was first described by Fehleisen.[1] The cocci grow in serpentine chains. They are small, varying from 0.3 μ to 0.4 μ in diameter; they are, however, somewhat larger than the streptococcus pyogenes. The culture of the coccus upon gelatin develops slowly, and appears as a very delicate grayish-white film, not unlike that of the streptococcus.

The question of the identity of these organisms is still a mooted one, although the feeling at present tends to the belief that the streptococcus of erysipelas is a specific organism. It has been suggested by some observers that in the suppurative forms of erysipelas pus is developed by the action of the pyogenic cocci; others believe that the streptococcus of erysipelas when developing in the subcutaneous tissue has a more virulent local action and may become pyogenic.

The cocci are found in the capillary lymphatics of the skin chiefly, but are also occasionally seen in the capillary blood-vessels and small veins. The growth of the organism is most active near the red margin of the erysipelatous blush. The virus may be transmitted to different parts of the body through the circulation, and the constitutional disturbance is probably due to the presence of the cocci or their ptomaïnes in the circulating blood. The virus gains entrance to the body almost invariably through a wound: even in the so-called cases of idiopathic erysipelas the cocci find their way through some minute abrasion in the skin.

The clinical evidence of the contagiousness of erysipelas is abundant. Stillé[2] reports the following striking example: In 1852 a man arrived in Platte county, Missouri, suffering from erysipelas of the face. He was nursed by a farmer, who himself fell ill of the disease. A second farmer, who assisted in nursing these two patients, was seized by the disease, and subsequently six other persons, who helped to nurse in their turn, were attacked. No other case occurred in the neighborhood.

The occurrence of erysipelas following vaccination was so frequent in Boston in the winter and spring of 1850 that vaccination was temporarily abandoned. The disease was probably not conveyed in the vaccine virus, but by an unclean instrument.

The close relationship of erysipelas and puerperal fever has been recognized by many authorities, and the impropriety of attending a case of confinement after handling erysipelas is now well understood. Trousseau describes an epidemic of puerperal fever which rendered the closing of a hospital necessary. In the hospitals to which pregnant women were transferred erysipelas broke out among the surgical cases in many instances.

Exposure to cold was for a long time supposed to be a cause of ery-

[1] *Die Etiologie des Erysipels*, Berlin, 1883.
[2] *International Encyclopædia of Surgery*, vol. i. p. 165.

sipelas, but it acts undoubtedly as a predisposing cause only, rendering the patient debilitated and therefore more susceptible to the disease. The spring and late winter months are regarded by many surgeons as a particularly favorable season for the development of the disease.

Erysipelas is comparatively rare in childhood, although it is seen in badly-arranged lying-in hospitals as *erysipelas neonatorum* when puerperal fever prevails. It does not occur so often in old age as in the prime of life.

Certain constitutional conditions, as alcoholism and diabetes, are supposed to act as predisposing causes, and some individuals frequently attacked by erysipelas are supposed to have a predisposition to the disease.

Symptoms.—The disease usually manifests itself at first by a chill, with fever and symptoms of gastric disturbances. The tongue is coated, and there is often a sense of oppression at the epigastrium, and some enlargement of the lymphatic glands belonging to the vessels leading from the point of infection. An examination of the wound does not, however, show any origin, as yet, of an infective inflammation. Occasionally the constitutional disturbance is so slight as to pass unnoticed, and the first sign of any disorder is in the wound itself. In twenty-four to forty-eight hours from the time of the beginning of the attack there is an itching or burning sensation in the vicinity of the wound and the skin becomes tender to the touch. There is at first a blush on the skin in the vicinity of the wound, which gradually deepens in tint and has a more dusky hue than the rose color of hyperæmia. There is a yellowish tinge mingled with the red, and this becomes more evident upon pressure, which shows a yellow stain to the diseased part during the moment in which the blood is pressed aside. The swollen tissues become tense and hard and do not pit on pressure. The swelling is most evident about the eyelids, where the skin lies loose, and also about the genitals. As the swelling and infiltration of the part increase, small vesicles form which may at times attain considerable size.

When the local inflammation is fully developed it shows a tendency to spread, and the outline of the diseased part is usually well marked and is often quite irregular. The inflammation runs its course at any one particular point in three or four days, but in the mean time it has invaded new regions, and this process may go on for a considerable period of time, and the surfaces involved in the inflammation are often quite extensive [illegible]. It may even revisit parts which have already been infected and are convalescent from the original attack. The tendency to recur is a marked feature of the disease, but so also is the tendency to recovery, and it is rare that the attack lasts longer than two weeks. As the inflammation subsides there is an abundant desquamation, and, as in the superficial form of erysipelas there is no suppuration, there is a complete return to the normal condition of the skin.

The condition of the wound during an attack of erysipelas varies greatly. In the early stages of the healing process a wound the edges of which are apparently may open, the interior presenting a sloughing appearance, and in the severer forms extensive destruction of tissue may take place, with [illegible] vessels of considerable size, producing severe hemorrhage. At other times, particularly when the disease

has attacked a wound in the stage of granulation, there appears to be little local disturbance, and the healing process may go on even more rapidly than before.

The constitutional symptoms correspond pretty closely with the amount of local inflammation in the majority of cases. Accompanying the gastric disturbance there are usually a chill and a rapid rise of temperature, followed by a slight fall on the following morning. The subsequent changes of temperature are most erratic, corresponding to the amount of inflammation—as a rule, however, showing the remittent type.

The tongue is heavily coated, and there may be vomiting and diarrhœa. In the most severe cases there may be delirium, and the disease shows a tendency to assume a typhoid type.

The variety of erysipelas known as *facial erysipelas* is often called idiopathic, as it does not appear to take its origin from a wound. The virus in these cases probably obtains an entrance through some small wound, abrasion, or pustule in the skin. The disease is first observed on the nose or near one of the lachrymal ducts, and spreads slowly along the lines of the cheek beneath the orbit in the direction of the ear. As it approaches the temple it may rise to the forehead and invade the scalp, or it may turn downward to invade the neck. The chin is rarely involved. In mild forms the disease gradually fades away as it reaches the ear, and the amount of constitutional disturbance is in such cases very slight. In the severer types of facial erysipelas the amount of swelling is usually very great; the eyelids become œdematous, and the eyes are closed, the disfigurement becoming at times so great that the patient is unrecognizable. The color of the skin is scarlet, and the surface is covered with vesicles which here and there run together, forming bullæ of considerable size. The lymphatic glands in front of and behind the ears are enlarged, and when the scalp is invaded the glands in the back of the neck are involved. In the severer forms of facial erysipelas, particularly if the scalp be involved, there is delirium, and a slight tendency to delirium is noticed even in mild forms of the disease. This appears to be caused either by reflex nerve-irritation, or by a vasomotor disturbance causing hyperæmia of the meninges, or by an extension of the septic processes through the orbit to the membranes of the brain. Fortunately, the latter complication is of rare occurrence, and with the subsidence of the inflammation of the skin the cerebral symptoms usually disappear.

The tendency of the inflammation to involve the deeper tissues of the orbit is characteristic of the graver forms of erysipelas, and blindness is sometimes caused by the extension of the septic process to the eye itself, producing either a panophthalmitis or degenerative changes in the optic nerve. A rare complication is the formation of an orbital abscess.

The **duration** of facial erysipelas, like that of other forms, is quite variable. In mild cases the disease rarely lasts beyond one week; in the severer types, or in cachectic individuals, the inflammation may last several weeks before it entirely disappears.

PHLEGMONOUS ERYSIPELAS.—When the disease spreads to the deeper tissues the virus appears to assume greater activity. The amount

of swelling is in such cases much greater, and the skin becomes tense and hard. Vesicles form, which are sometimes filled with bloody fluid, and the surrounding parts are swollen and œdematous. The constitutional disturbance is great. Chills frequently occur, and the fever assumes a typhoid character. As pus forms in the subcutaneous tissue, the skin above loses its tension, and becomes boggy and more or less movable on the parts below. A free incision gives vent to sanious pus, mingled with shreds of sloughing tissue which have been likened to masses of wet blotting-paper. The suppurative process generally extends for some distance beneath the surface, and several incisions are usually necessary to drain the parts properly. The muscles may be separated from one another, and even joints may be involved in the septic process.

In some cases gangrene of the skin may occur, and on such occasions the skin becomes a dusky-red in color and large bullæ form filled with bloody serum. It is principally in old and feeble individuals that such a complication occurs. It is known as *gangrenous erysipelas*. The constitutional disturbance is in such cases very great, and many patients will succumb with symptoms of pyæmia or of septicæmia.

Erysipelas Neonatorum is most frequently seen in hospital practice. It takes its origin from the granulating surface of the stump of the umbilical cord. The slight blush about the navel is at first accompanied by but little fever. As the disease progresses the septic process may extend over the abdomen and involve the genitals and thighs. There is then high fever, and the child cries and is restless. In the later stages collapse supervenes, and the child dies on from the sixth to the tenth day of the disease. Gangrene is an occasional complication of this form of erysipelas. The disease may spread along the hypogastric arteries or the umbilical vein, and peritonitis may occasionally occur in consequence.

Erysipelas of Mucous Membranes occasionally occurs. When the pharynx is involved the color of the throat is a dark red, and there is a tendency to dyspnœa and difficulty in deglutition. There is also a marked enlargement of the cervical glands. The thorax may become the seat of diphtheritic inflammation, and suppuration may take place in the submucous tissues. The mouth may also be involved in the inflammatory process, and the tongue then becomes greatly swollen and congested, giving rise to that variety of disease known as "black tongue."

The disease is said to extend along the air-passages to the lungs, giving rise, perhaps, to œdema of the glottis or to septic pneumonia or *pneumonia migrans*. Such forms of erysipelas are extremely rare at the present time, and were observed principally in those malignant epidemics which have already been mentioned.

Erysipelas may occasionally extend from the vulva to the vagina and from the nates into the rectum.

Pathological Anatomy.—An examination of the principal seat of the disease—the skin—shows that there is a considerable exudation in the rete mucosum and in the upper layers. The superficial network of lymphatics is filled with streptococci, which are most numerous near the margin of the inflammation. There is a considerable hyper-

æmia of the blood-vessels of the affected part, and the surrounding tissues are infiltrated with leucocytes. In some types of erysipelas minute abscesses, which during life have escaped observation, are often found in the cutis.

The changes observed in the circulating blood are supposed to be due to the micrococci, although they are rarely found there in large numbers. The red corpuscles are found to assume a crenated appearance, and dissolve and run together readily. The white corpuscles are usually increased in number. Endocarditis is occasionally observed. The gastric symptoms appear to be due to the condition of the system, rather than to any local change. Catarrhal ulcers are, however, sometimes found in the small intestines. The brain and membranes are hyperæmic and œdematous in the severe forms of facial erysipelas. Suppurative meningitis is, however, extremely rare. Enlargement of the spleen is often found, and there is frequently some cloudy swelling in the kidneys. The parotid gland may also become inflamed.

The curative influence of erysipelas (érysipèle salutaire) has long been recognized. Wounds heal more rapidly, chronic inflammations of the skin disappear, and old ulcers begin to granulate. Tilmans reports several cases of sarcoma of the face and neck which either disappeared after an attack of erysipelas or were greatly reduced in size.[1] In one case the patient died of the erysipelas, and the cells of the tumor were found to have undergone extensive fatty degeneration. Fehleisen, in order to demonstrate the specific character of the streptococcus of erysipelas, inoculated man on several occasions with success, the human inoculations being used also for the purpose of testing the curative character of the virus. A death having occurred in the hands of imitators of this method, the experiments were abandoned.

Recently, Coley[2] has experimented with the virus, and has collected 38 cases of malignant disease in which erysipelas had occurred either by accident or intent. There were 17 cases of carcinoma, of which 3 were permanently cured, and of 17 cases of sarcoma 7 were well and free from recurrence from one to seven years after the attack of erysipelas. As in some cases when the pure culture has been used death has followed the inoculation in the hands of other surgeons, Coley has substituted the toxic products of the erysipelas coccus for the pure culture. They are thus obtained: The streptococcus is planted in bouillon culture and allowed to grow for six weeks, when the bouillon is filtered. The filtered material contains no bacteria, but is rich in toxic products.

Spronck's method of preparation is as follows:[3] The streptococcus is planted in two large flasks of equal size nearly filled with bouillon. The cotton plugs are covered with a layer of paraffin. The flasks are subjected to a temperature of from 33° to 35° C. for fifteen days. After the purity of the culture has been verified, the contents of one of the flasks, to which 5 per cent. glycerin has been added, is subjected for three hours to a current of steam at 100° C., and is finally reduced to one-tenth its volume by boiling. After cooling this liquid is added to the contents of the other flask and the mixture is filtered.

[1] *Deutsche Chirurgie*, Lieferung 5, 1880.
[2] *American Journal Medical Sciences*, May, 1893.
[3] *Annales de l'Institut Pasteur*, No. 10, 1892.

The **diagnosis** of erysipelas is not easy to establish definitely in the early stages. The chill, the gastric symptoms, and the enlargement of the lymphatic glands are indications which should cause the surgeon to examine the wound carefully for signs of the disease. It is not until the blush appears that a certain diagnosis can be made. The doughy swelling with tenderness of the skin and the irregular raised margin of the inflamed area serve to distinguish it from erythema, which may originate in some local irritation or inflammatory process. There may at times be difficulty in deciding between phlegmonous erysipelas and diffuse suppuration of the cellular tissue. This latter complication arises usually from a wound, and from the beginning the signs of a deep-seated suppurative inflammation are manifest, whereas in erysipelas the inflammation begins upon the surface, and the superficial changes are then not a marked feature.

The **prognosis** of erysipelas is, as a rule, favorable. There is a tendency on the part of the disease to self-limitation, and the disease does not remain in any one spot more than four or five days. If erysipelas attacks a wound during the early stages of the healing process, it is more likely to be severe than during the granulation stage. It varies also with the age of the patient. In very young infants it is a most serious condition, and in the aged it is with difficulty that the disease is thrown off, particularly in the traumatic form of erysipelas. In facial erysipelas, which attacks old people so frequently, the disease is often very mild in its course.

The severity of the disease may be said to vary according to the resisting power of the patient. The tendency to relapse should always be borne in mind.

Although the disease may not be severe in its type, it may produce fatal complications, such as secondary hemorrhage. The sight may be lost in facial erysipelas, and spasm of the glottis may occur if there is great swelling in the neck during an attack. The effect of antiseptic surgery seems, however, to render the attacks, as a rule, milder.

Treatment.—The treatment of erysipelas may be both local and constitutional. In general, it may be said that the treatment should be supporting and that depletion should be avoided. The diet should be carefully adapted to the disturbed digestive functions, but should be nutritious. Alcoholic stimulants may be used freely in the asthenic cases, but care should be taken as to over-stimulation where there are symptoms of cerebral hyperæmia.

The use of iron has been strongly recommended in England. Bell recommended 25 drops of the tincture of the chloride of iron every two hours, day and night. Iron is supposed to exert a favorable action upon the red blood-corpuscles and to have a constringing effect upon the blood-vessels. Quinine may be combined with it, but these remedies are not so much used since more dependence has been placed upon the local treatment. Camphor, digitalis, and aconite have also been recommended for this disease.

Antipyretics exert but little influence upon the fever, and are to be avoided, owing to their depressing influence upon the heart's action. Delirium may be relieved by the use of the bromides or chloral, and

opium in some form may be needed to ensure relief from pain and to give repose.

Among local remedies, iodine enjoyed for a long time a great reputation, as it was supposed to prevent the spread of the local inflammation. It has now been replaced by antiseptics. The effect of antiseptic drugs, applied to the surface of the skin, upon the bacteria in the capillary lymphatics is not as great as might be supposed. Although the skin absorbs certain drugs freely, particularly those containing carbolic acid, it is probable that the organisms are restrained in their activity to a certain degree only, and are rarely destroyed by this agent.

Carbolic acid may be applied to the part in an ointment in the strength of 1 : 100, or it may be used in an antiseptic poultice which has been dipped in a solution of 1 : 200. James C. White recommends a lotion containing 1 drachm of carbolic acid to 4 ounces each of alcohol and water. This should be applied upon a cloth, and, as it evaporates quickly, should frequently be renewed. It is well adapted to facial erysipelas and to parts that can conveniently be exposed.

Carbolic acid can theoretically be brought more intimately in contact with the bacteria by subcutaneous injections. These should be made along the margin of the diseased area. The difficulty of introducing a sufficiently large quantity of the solution at the most needed points is an obstacle to the success of this method. It should always be remembered that carbolic poisoning may result from a too free use of the drug, and the urine should be watched for the characteristic olive-colored staining while this treatment is employed.

Creolin and phenyl are preparations which are good substitutes for carbolic acid in antiseptic poultices. Phenyl (sulpho-naphthol) may be used in a strength of 1 : 250. Ichthyol may be applied when it is desired to avoid strong antiseptic dressings. Mild zinc ointment and plain vaseline are comfortable applications. The frequent application of liquid vaseline to the face, or a solution of carbolic acid in oil 1 : 100, with a camel's-hair brush, is a mode of treating facial erysipelas which is both comfortable and effective. If it is desired to retain a dressing upon the face, this may be done by means of strips of gutta-percha tissue, which is light and easily holds oily substances in contact with the skin.

When the infective process goes on to suppuration, as in phlegmonous erysipelas, drainage must be obtained by free incisions as the surest means of arresting the spread of the disease. The knife should penetrate as far as the subcutaneous cellular tissue, as it is at this point that pus will be found. The sloughing tissue should be removed as thoroughly as possible, and the infected area disinfected by antiseptic solutions. Carbolic acid and peroxide of hydrogen are probably more effective agents for this purpose than corrosive sublimate. Antiseptic baths may be used, the limb being submerged for half an hour once or twice a day in weak antiseptic solutions.

When pus forms in the orbit, it is necessary to make an early and deep dissection in order to reach the point of infection and prevent grave injury to the optic nerve.

Erysipelas is now generally recognized as a contagious disease, and it is therefore important that early attention should be given to the isolation of the patient from other surgical patients, and great care should be

exercised by the surgeon and his assistants to avoid the transmission of the disease to others. In hospitals such cases should be transferred to a special ward and placed under the charge of a member of the staff specially selected for the purpose. In no case is careful attention to the hygienic surroundings of the patient of greater importance. A thorough ventilation of the apartment and frequent change of the clothing and bedding are precautions which may serve to favor the removal of the germs of the disease as they accumulate and to ward off a reinfection of the patient. Relapses, which are so characteristic of erysipelas, may in this way frequently be avoided. The patient should not be released from his isolation until all tendency to desquamation has ceased.

III. Tetanus.

Tetanus is an infectious disease, generally traumatic in origin, characterized by painful contractions of the muscles, beginning with those of the jaw or the neck and affecting progressively the muscles of the trunk and the extremities. It is accompanied by convulsive paroxysms, and is due to the presence of a bacterial poison in the blood and tissues.

Etiology.—The *bacillus tetani* was first discovered in 1885. It is a very slender rod with somewhat rounded ends. Spore-formations which are spherical in form take place at one end of the rod, and, being considerably greater in diameter than the rod, give to the bacillus a drumstick or pin shape. It is a strictly anaërobic organism, and grows at a room temperature in the usual culture media. It rapidly dies when exposed to the air. Spores are formed in cultures kept in the incubating oven at 36 °C. at the end of thirty hours. The spores retain their vitality in a desiccated condition for several months. The bacillus is colored by methyl-blue and fuchsin. The method of Ziehl may be employed for double staining of bacilli and spores. It can be cultivated in cultures of gelatin mixed with grape-sugar. In stab-cultures development takes place along the line of puncture a considerable distance below the surface in innumerable radiations, giving the appearance of an inverted fir tree.

Through the researches of Brieger and Kitasato a toxic substance has been obtained called *tetanin*. This substance has been obtained not only from cultures, but from the tissues and blood of individuals affected with tetanus. A substance known as *tetanotoxin* and also as *spasmotoxin* has also been obtained.

The organism is found principally in the tissues near the wound, and rarely in the blood, the internal organs, or the central nervous system. Injected into animals, the organism produces symptoms of tetanus in twenty-four hours, and at the autopsy a slight infiltration is seen at the point of injection, but no coarse pathological changes are found elsewhere. Few bacilli are found, and the symptoms produced are consequently ascribed to the tetanin, which is supposed to disseminate itself through the body.

The bacilli are found in the superficial soil in temperate, and particularly in tropical, regions, in the mud of the streets, in garden soil, and in crumbling masonry, and they have been observed frequently in manure. Although so widely distributed, these organisms are rarely able to exert their pathogenic action, owing to their anaërobic nature.

It is only in deeply-punctured wounds, therefore, that we find the conditions favorable for their growth.

Among the predisposing causes of tetanus meteorological influences have been supposed to play an important part. Epidemics of tetanus are reported as following a sudden change of weather after great battles. In tropical countries the type of the disease is said to be much more virulent.

Injuries of nerves have been supposed, by older writers, to give rise to tetanus, and the disease has been supposed to follow injuries to certain portions of the body, as the hands and feet; but statistics do not appear to support these views, for the disease is known to occur after injury in almost every locality, and has even occurred where no appreciable lesion could be found.

Age appears to exert a certain influence. Yandell found that in 7 per cent. of the cases collected by him the patients were under ten years of age. These figures do not include cases of trismus nascentium. The disease is said to be rare among the aged.

Although cases of idiopathic tetanus are occasionally reported, it is probable that the disease is always traumatic, the point of inoculation being so small as frequently to escape notice.

Varieties.—Tetanus is both acute and chronic. Puerperal tetanus and trismus nascentium are usually considered separately from traumatic tetanus, but are etiologically in no way to be distinguished from this form of the disease.

Acute tetanus usually appears during the first week after the infliction of the wound. In chronic tetanus the symptoms are found in the second week, and sometimes even later than the fourteenth day.

Symptoms.—After a comfortable night's rest the patient usually wakes with the sensation of having taken cold. He complains of a stiff neck, but attaches no importance to the symptom. During the day there is a slight stiffness of the muscles of the jaw which makes it difficult for him to open his mouth. The muscular rigidity is presently followed by powerful muscular contractions, which soon become so painful and continuous that the jaw cannot be opened, and considerable difficulty is experienced in swallowing even liquids. The masseters are found to be in a state of rigid contraction (trismus or lockjaw), and the muscles in the back of the neck are so unyielding that it is difficult to approximate the chin to the sternum. The muscles in the abdominal parietes are soon found to be firm and rigid, and toward the end of the first day the muscles of the back will also become involved, producing arching of the spine, or opisthotonos. The muscular contractions, which are now almost continuous, are known as tonic contractions. Attempts to swallow are painful and ineffectual, owing to the paroxysmal increase in the muscular contraction. The patient usually suffers from retention of urine.

On the second day the jaws are locked as firmly as before, and nearly all the muscles of the body, except those of the upper extremities, are involved. The arms are only partially affected, but the lower extremities are usually rigidly extended. The muscles of the face are also now affected, the eyelids are contracted, the nostrils raised, and the mouth puckered in such a way as to give a peculiar expression to the patient

(risus sardonicus). The eyes are drawn in and are partially closed, and occasionally there is strabismus.

Any disturbing influence brings about an exacerbation of the muscular spasm which exists throughout the body. The muscular contractions are exceedingly painful, and any attempt to prevent them or to straighten a limb may lead to rupture of the muscular fibre.

The attitude of the patient in bed is characteristic. He lies usually upon his side, and is apparently motionless. Close inspection will, however, show that the head is drawn rigidly backward and that the arch of the spine is greatly increased. The rigidity of the muscles of the mouth does not permit distinct articulation, and the patient emits only muffled groans in answer to questions. The spasm of the sphincters renders movements of the bowels and evacuation of the bladder extremely difficult.

There is but little pyrexia at first, and there is usually no characteristic temperature-curve. There may be a rise of temperature during the later stages of the disease, and even post-mortem. Diaphoresis is a marked feature of the disease, occurring principally after each convulsion, and doubtless aids in preventing an excessive rise of temperature.

But little sleep is obtained, owing to the almost continuous muscular contraction. Short periods of slumber may be secured by the use of drugs, but the patient is soon roused by renewed convulsive movements. During these attacks, which last usually a few seconds only, there are some cyanosis of the face and foaming at the mouth. There is also marked dyspnœa; the pulse is greatly accelerated; the muscular contractions usually produce at this time a marked opisthotonos.

Attempts to swallow often bring on spasm of the glottis, and death has occurred during such a crisis. Spasm may also be produced by attempts to expectorate the mucus which has accumulated in the throat. As the result of these constant muscular efforts and the loss of nourishment and sleep there is great prostration. The face is pale and emaciated, and if not convulsed there is an expression of great apprehension. The voice is feeble, and the skin is constantly bathed in sweat. The mind is clear, and the patient is fully sensible to the agony of his disease. During the last moments the tetanic spasms may relax, but they are usually maintained until the end.

In chronic tetanus the period of incubation is longer than that of acute tetanus, the first symptoms appearing usually in the second or third week after the injury. The order in which the symptoms appear is the same as in acute tetanus. The development of the early symptoms may also be as rapid as in the acute form, but there are frequent periods during which the patient obtains a respite from the muscular contractions. During these intervals the patient is able to take nourishment, and his strength is correspondingly maintained. As time passes these intervals become longer and the muscular spasms are less severe, and the patient has an opportunity to obtain sleep. Prostration is, however, extreme, and any unusual excitement or irritation brings back the spasms. The period of convalescence is liable to be interrupted by numerous relapses. The disease is likely to be greatly prolonged in this way.

HEAD TETANUS occurs after injuries in the region of distribution of the cranial nerves. It is characterized by spasm of the pharyngeal muscles

and paralysis of the facial nerve. There is also trismus, and occasionally tetanic contractions of the muscles of the neck and abdomen. This form of tetanus occurs usually after a wound in the face. The difficulty in swallowing has given rise to the term "tetanus hydrophobicus." Like other forms of tetanus, it may be either acute or chronic.

There is nothing characteristic in the condition of the wound. According to Poncet, the suppurative process is less healthy in character and the tissues appear to be in a state of irritation. Occasionally a slight blush is seen along the edges of the wound, or there may be evidence of a lymphangitis. Occasionally a slight pricking sensation, and even pain, is experienced in the affected limb. Experiments by Buschke and Oergel show that granulation tissue taken from the wound of a boy who died from tetanus, and inoculated into mice produced symptoms of tetanus with a fatal result.

Wounds of the extremities are said to be more frequently followed by tetanus than those of any other region. This is borne out by the observations of Yandell and the statistics given in the *Surgical History of the War of the Rebellion.*

This apparent preference of locality is probably due to the fact that punctured wounds are more frequent in the hands and feet. The presence of a foreign body is supposed to be a predisposing cause, but tetanus may follow even slight injuries. The fact that tetanus is frequent in military surgery is, however, due not only to the penetrating nature of the wounds, but also to the frequent presence of a foreign body.

Post-mortem Changes.—Evidence of inflammation of the brain and meninges is wanting, but signs of inflammation in the nerves and in the cells of the medulla and cord have been observed. Grinelle in an analysis of 52 cases reports that 29 presented lesions in the cord and membranes, in 3 changes were noticed in the brain, and in 11 in the nerves and muscles. Lockhart Clarke found a disintegration and softening of a portion of the gray substance of the cord. Ranvier was, however, unable to find any pathological changes in the cord in four cases of tetanus. Laveran found connective-tissue changes in the tibial nerve of a patient who died of tetanus following amputation of the leg. Jewell thinks the principal seat of the disorder is in the posterior cornua and the contiguous central gray matter.

Diagnosis.—The diagnosis of tetanus may be difficult in the earlier stages of the disease. Stiffness of the muscles of the neck and jaws may be due to inflammatory affections of the mouth or teeth or to abscess of the cervical glands. Rheumatic inflammation of the temporo-maxillary articulation is usually accompanied by sufficient signs of local inflammation to be readily recognized. Hysterical contraction of the masseter muscles is not liable to give rise to a mistake in diagnosis, as sufficient time will usually have elapsed to enable the surgeon to exclude tetanus. Temporary spasms following the dressing of a painful wound are not likely to be mistaken for tetanus.

Cases of tetanic spasm due to peripheral irritation by scars or foreign bodies are reported, and in some instances terminate fatally. Some of these cases may be true tetanus, but others are probably examples of severe reflex irritation.

In cases of strychnia-poisoning there is spasm of the muscles of the

too mild a remedy to produce an appreciable effect in the more active stages of the disease.

Calabar bean, or its active principle, when given in small doses, relieves the muscular contraction; the jaws relax, and the head reposes quietly upon the pillow. If given in large doses, the spasms appear to be greatly aggravated. Poncet explains the favorable action of the drug by its effect upon the conductibility of the motor nerves by which the muscular system is, as it were, isolated from the nerve-centres. He prefers to give it by the mouth rather than by subcutaneous injection, as the dose can be more carefully regulated and the action of the drug observed by this method. From ½ to 1 grain of the extract may be given by the mouth every four hours, and 15 to 20 drops of a 1 per cent. solution may be injected subcutaneously. The statistics of Knecht give a mortality of 45 per cent. in 60 cases in which this drug was used.

Warm baths and diaphoretics have been used extensively in the treatment of tetanus, doubtless in imitation of Nature's method of giving relief, as diaphoresis is a frequent symptom of the disease. Vapor baths are probably the most efficacious way of carrying out this treatment, as they are less likely to disturb the patient and thus aggravate symptoms. In no disease should the comfort of the patient be so carefully studied, and every effort should be made to avoid disturbance or irritation of any kind. The value of skilled nursing is shown nowhere to greater advantage than in this disease.

Due attention should be given to the wound, and an effort should be made thoroughly to disinfect it. The wound should consequently be laid open, and its surfaces not only exposed to the action of oxygen, but to powerful antiseptics, as in this way the amount of the virus may possibly be diminished. Punctured wounds should be opened sufficiently to admit of thorough disinfection. It is possible that the present aseptic method may permit the early closing of a punctured wound, and thus favor the development of the tetanus bacilli in the deeper layers of the wounded part. The old-fashioned poultice by setting up suppuration favored a discharge of all poisonous material. In some cases the scar is red, tender, and swollen. Such scars should be excised, and in all cases it is advisable to open and explore the cicatrix, as in some instances particles of dirt have been removed with the cicatricial tissue.

Experiments upon animals have shown that immunity can be obtained by inoculations with minute doses of the poison or with a filtrate which has been exposed to a temperature sufficient to destroy its activity (Kitasato). Immunity was also obtained for a certain time by inoculating animals with the filtrate from the culture of the tetanus bacillus, and subsequently by inoculating them at the same point with a solution of terchloride of iodine. It was further found that the blood-serum of an immune animal when injected into another animal protected it from the effects of the inoculation with the tetanus bacillus, and that inoculated animals in whom the tetanic symptoms had already made their appearance were preserved from death by the injection of the blood-serum of an immune animal (Sternberg). Tizzoni and Cattani gave the name "tetanus antitoxine" to the substance existing in the blood of an immune animal which produced these results. Behring found that the more intensely the animal was inoculated to render it

immune, and the longer it had remained inoculated, just so much less of its serum was required to cause immunity in another animal. A more powerful dose was, however, required for therapeutic purposes to check tetanus which had already made its appearance.

These interesting experiments have led, as yet, to a limited employment only of the antitoxine in the treatment of tetanus in man. A number of successful cases have been reported, but the treatment seems to have been employed almost invariably in chronic tetanus. In a case reported by Rotter treatment was not begun until the fourteenth day of the disease: 36 grammes of blood-serum from an immunized horse, with 5 per cent. of carbolic acid, were injected into the back. The injections were continued for five days, and the patient recovered, the symptoms rapidly yielding to the treatment.

RABIES; HYDROPHOBIA; LYSSA.

By HERMANN M. BIGGS, M. D.

Rabies is an acute infectious disease occurring in many species of animals and in man. It is transmitted solely by inoculation from an infected animal, usually through a bite, and is characterized by a long period of incubation, paroxysmal convulsions, great mental disturbance and excitement, fever, often by general motor paralysis, and terminates almost invariably in death. When rabies occurs in man it is commonly called hydrophobia, because of peculiar spasms of the muscles of the throat which follow any attempts at deglutition, or which may occur even at the sight of water or food. These are extremely painful and produce great terror in the patient, and hence the name "hydrophobia."

Rabies in Animals.—Rabies may occur in many species of animals besides dogs, especially in those of the canine genus, wolves and foxes, and in skunks. Cats are sometimes affected, although less commonly than dogs. It may also be transmitted to herbivora—to horses, cattle, sheep, goats, rabbits, pigs, guinea-pigs—and less readily to other species of animals, either experimentally by inoculation or through the bites of rabid dogs. Adami has reported a very extensive epidemic of rabies which occurred in 1885 among the deer in Richmond Park in England and afterward in the park of the marquis of Bristol. Rabies is rarely transmitted from other animals than those of the canine genus.

In dogs the symptoms of rabies vary somewhat, but the first real symptom, usually not noticed, is a rise in temperature. This is followed by dulness, with an indisposition to move; later, the animal becomes shy, suspicious, restless, and irritable, often snapping at anything which comes near. At this period he frequently leaves home if he is not confined, and may make long excursions, snapping at everything in his way, and particularly attacking other dogs or animals. Throughout this early period there is a depraved appetite, the animal rejecting the usual food and devouring hay, cloth, wood, coal, gravel, fæcal matter, or even its own hair or tail. This symptom is important and rather characteristic, although it is by no means pathognomonic, for frequently it may be seen in other diseases than rabies. Almost invariably the bark is altered; it is hoarse, unlike its usual tone, and terminates with a peculiar howl. In one variety of the disease in dogs there is intense, almost maniacal, excitement; in another there is early paralysis of the muscles of the jaw (so that it hangs down and allows frothy saliva to escape from the mouth), followed by general motor paralysis. In all varieties there is commonly weakness of the muscles of deglutition: this interferes with swallowing, but at no time in the disease is there any fear of water. A rabid dog will often plunge his

nose and partially submerge his head in a dish of water or in running water. There exists a popular and dangerous fallacy regarding this fear of water, which is no doubt based on the name "hydrophobia." It is commonly believed by the laity that a dog cannot be rabid if he drinks or submerges his head in water.

After a longer or shorter period, in all cases paralysis appears, and the dog staggers in attempts to walk, and often falls. Finally, the weakness in the legs becomes so marked that the animal is unable to stand, and dies completely paralyzed. A distinction has often been made between dumb or paralytic and furious rabies, but the difference is largely one of degree of excitement, which may depend upon the conditions surrounding the animal in the early part, and the rapidity of the course, of the disease. In every case, ultimately, there is paralysis more or less complete. A change in the disposition of an animal, shyness, restlessness, illusions of sight and hearing (shown by snapping at invisible objects in the air, elevation of the ears, an attentive position, due to the hearing of sounds which do not exist), perversion of appetite, wandering from home, and similar modifications of the usual appearance, action, and manner, are all symptoms suggestive of the disease in the early stage.

It is an important point to determine when a rabid animal can transmit the disease. Experimental observations have shown that there is commonly an elevation of temperature in dogs before any other symptoms of the disease appear, and at this time, and even perhaps for twenty-four or forty-eight hours or more before the elevation of temperature, the bite of the animal may be virulent. In this way are explained the cases of rabies which have been reported as resulting from the bites of animals apparently in perfect health, and to this, no doubt, is due the belief which formerly existed that under certain conditions the bites of animals might produce hydrophobia when they themselves were not affected by the disease.

Rabies in dogs almost invariably terminates fatally. There are, however, some very rare cases in which recovery occurs. The duration of the disease is variable, sometimes death occurring in twenty-four or thirty-six hours, while in other cases it is postponed for seven, or even very rarely for nine or ten, days. When a person has been bitten by a dog, whether suspected of being rabid or not, instead of destroying the dog immediately, as is too frequently done, the animal should be placed in confinement and kept under observation for several weeks if necessary, so that it may be with certainty determined whether the dog was or was not rabid. If the dog is destroyed, it is of course impossible to determine whether it was rabid or not, except by the inoculation of other animals by the subdural method of Pasteur, with the medulla or spinal cord. As will be seen later, however, a probable diagnosis can frequently be based upon the autopsy-findings and the microscopical examination of certain portions of the brain.

In the rabbit the symptoms, as produced by inoculation, commonly resemble those of dumb or paralytic rabies as it occurs in dogs. They are not unlike those found in the human being in acute ascending paralysis, and consist in dulness with some pyrexia, followed by weakness in the hind legs, which gradually increases and extends forward

until a complete general paralysis results. The animal lies then upon its side, with difficult and labored respiration and complete motor paralysis.

The period of incubation in animals is exceedingly variable, especially when the disease is produced by subcutaneous inoculation. It varies from seven or eight days to a month or more. In the subdural method of inoculation of Pasteur, after the virus has been passed through a series of rabbits the period of incubation in these animals becomes permanently shortened to about seven days, and remains uniform at this point when the inoculations are made by this method.

Distribution and Frequency.—For a long time it was assumed that rabies was confined to, or was chiefly found in, temperate regions. Further observation has shown, however, that it occurs in all parts of the world, excepting perhaps in Australia, New Zealand, and one or two other isolated localities where it apparently has not yet been introduced. The frequency with which the disease occurs varies greatly. Like other epizootic diseases, it often appears in epidemic form. It can be entirely eradicated by the efficient enforcement of a law providing for the muzzling of dogs. Rabies has become practically an unknown disease in many parts of Germany and some other European countries as the result of properly enforced laws regarding muzzling.

Under all conditions rabies is a comparatively rare disease in man. Boudin, in a communication to the French Academy in 1863, gave the number of deaths from hydrophobia in Prussia, from 1854 to 1858, as 196; in Belgium, from 1856 to 1860, as 26; in England, from 1853 to 1857, as 100; in Scotland, from 1855 to 1863, 10; in Sweden, from 1856 to 1860, as 42. In Ireland the number of deaths for ten years ending in 1879 was 21; in London, according to the Registrar-General's return, there were no cases from 1856 to 1862, 2 in 1863, none in 1864, 9 in 1865, 6 in 1866, 2 in 1879, 3 in 1880, 5 in 1881, 4 in 1882, 8 in 1883, 9 in 1884, and 27 in 1885. Muzzling was enforced in 1886, and the number suddenly fell to 9, all of which occurred in the early part of the year. In 1887 and 1888 there was not a single death reported. The number of cases occurring annually in this country has been very small, although the actual number cannot be determined. In New York City, during the ten years ending in 1891, there were in all 9 deaths reported to the Health Department as being due to rabies. In 1887 in the whole of the German Empire there were only 4 deaths from rabies. In France rabies is apparently more prevalent, although, according to the reports of Tardieu and Brouardel for the years 1850 to 1872, there were in all 685 deaths, an average of a little less than 40 yearly. Tardieu says of his reports that nearly all departments replied to his inquiries, and Brouardel, that about two-thirds were included in his. Since the public announcement of the discoveries of Pasteur regarding the preventive treatment of rabies, however, apparently the number of cases of infection has largely increased, if we are to assume that all those inoculated had really been bitten by rabid dogs, for from 1200 to 2000 Frenchmen have been inoculated each year.

Etiology of Rabies.—There is but one efficient cause of rabies, the introduction of a specific virus derived from a rabid animal. Of the nature of this virus we have as yet no absolute knowledge, but there

can be no reasonable doubt, reasoning from analogy, that it is a micro-organism of some kind. Numerous other causes have been commonly supposed to be efficient in the production of the disease. There are popular superstitions to the effect that the bite of an angry dog or of one in rut may be followed by rabies, that the disease is especially prevalent during the hot months of the year, and that certain breeds of dogs are particularly susceptible to rabies. These superstitions are not at all borne out by experience or statistics. Law quotes statistics from Bouley showing that in the winter months among dogs there occurred 755 cases of rabies; during the three spring months, 857; during the three summer months, 788; and during the three autumn months, 696; which indicated that the largest number of cases occurred in the spring months, but that there was really little difference in the number of cases occurring in any season of the year.

There are certain questions which arise in connection with the etiology of rabies which are of importance and interest. The virus undoubtedly resides, particularly in dogs, in the saliva and salivary glands. The disease was long ago produced in dogs by Majendie by inoculating them with the saliva of hydrophobic patients and of rabid dogs. Pasteur has shown that the virus exists after death in the central nervous system, particularly the medulla or spinal cord, and also in the peripheral nerves, as well as in the salivary glands, and that the disease may be produced more certainly and with a more uniform period of incubation when inoculations are made beneath the dura mater after trephining the skull than when they are made by subcutaneous injection of the virus. It is probable that the disease may be communicated from one human being to another, although no well-authenticated cases of this sort have been recorded. Medical men and nurses who are in attendance on cases of hydrophobia always escape, although the saliva is often thrown upon the faces, hands, or clothing. The virus is, as a rule, rapidly destroyed by decomposition, although one or two cases have been recorded where hydrophobia apparently resulted from accidental inoculation at the post-mortem examination of cases of rabies.

In a large majority of all cases in the human being the disease is contracted from the bite of a dog, in a very few cases from the bite of a cat, and occasionally, especially in Russia, from the bite of rabid wolves or foxes. Bites on uncovered parts of the body, as upon the face or hands, are far more likely to be followed by the disease than if inflicted upon portions covered with clothing, as in the latter case the virulent saliva is frequently entirely wiped off from the teeth. The disease has been caused by a rabid dog licking a scratch upon the hand, and apparently it has followed the scratch of a rabid cat, the animal's saliva having been probably thus introduced. There is absolutely no reason to suppose that the disease can ever result from the bite of any animal not suffering from rabies. Undoubtedly, the cases in which this is supposed to have occurred have been either otherwise inoculated or have been infected by an animal apparently well, but in which the symptoms had not yet appeared, as it has been shown that the saliva may be virulent for several days at least before the appearance of the disease. A large proportion of the cases occurring in the human being are in children,

because they are more likely to be bitten, and because they are more frequently bitten on exposed parts of the body. In rare instances the disease has been transmitted to human beings and to other animals from rabid cattle, horses, sheep, etc. In these animals the saliva may be also virulent.

The saliva from rabid animals will retain its virulence for a considerable period after having been dried. Pasteur has shown that the spinal cords of rabid animals which have been dried lose their virulence at the end of about fourteen days. Exposure to comparatively low temperatures also destroys the virulence of rabic virus; that is, exposure for one hour to a temperature of 50° C. The direct rays of the sun and exposure to the action of 1 per cent. sublimate solution or 1 per cent. carbolic solution for three hours have the same effect. Byron has shown that the virulence may be preserved by immersing the rabic spinal cord in pure glycerin or by sealing up aseptic pieces of the spinal cord in test-tubes.

The susceptibility of animals to the virus varies with the kind of tissue into which it is injected. Intravenous injections are not often followed by the disease. Injections into the muscular tissue are more frequently followed by infection than injections into the subcutaneous tissue, and the application of the virus to divided nerve-filaments is generally efficacious in producing the disease. Divestin, Zagari, Pasteur, and others have apparently shown that the virus extends from the seat of infection along the nerve-trunk to the spinal cord, and if the animals are killed at the proper time the virus may be found in the nerves leading from the part infected when it is as yet absent in other parts of the nervous system. Thus in bites of the posterior extremities it is present in the lumbar cord when absent in the cervical region or medulla. It is apparently sometimes present in the pancreas and lachrymal glands, and rarely in the secretion of the mammary glands; but it is usually absent from the blood, liver, spleen, and kidneys.

Incubation.—The incubation period of rabies in dogs varies widely. The shortest period is apparently six days, and the longest about eight months. In the majority of cases it varies between fourteen and thirty days. In horses, cats, sheep, and swine it is ordinarily from twenty to thirty days, but the period may be prolonged considerably beyond these limits. Bollinger says that in 60 per cent. of all cases in the human subject it is between eighteen and sixty days; in 6 per cent., between three and eighteen days; and in 34 per cent. the period is longer than sixty days. Cases have been recorded where the incubation has apparently been greatly prolonged to from one to three or five years. These cases, however, are not well authenticated, and in well-observed cases the incubation rarely, if ever, is more than twelve months. In 132 cases quoted by Fagg from the Registrar-General's reports, selected because the circumstances regarding the incubation were accurately known, the shortest incubation was eleven days—a case in which a child was bitten by a rabid cat; in 23 cases it was under a month; in 64, between one and two months; in 21, between two and three months; in 24 cases it was more than three months. The average incubation period is about six weeks, but the length is undoubtedly affected by the seat and severity of the wounds and the age of the patient. It is

shorter, as a rule, where the wounds are on exposed parts and very extensive, and is shorter in children than in adults. As has been stated, by the inoculation of rabbits with the spinal cord of others dead of rabies Pasteur was able to reduce the incubation period to about seven days, at which point it remained constant. This virus is known as "the fixed virus (*virus fixé*) of Pasteur."

Symptoms in Man.—The symptoms of rabies in man present a general similarity to those manifested in rabid animals, although the most striking symptom, that from which the disease in man has derived its name, is peculiar to him. The disease has been commonly called "hydrophobia" in man because during the furious stage violent spasms of the muscles of the pharynx and the elevators of the larynx and hyoid bone occur, which are associated with intense suffering. When the disease is fully developed these paroxysms are often brought on not only by attempts at swallowing, but even by the sight of water or food, or, in fact, by any peripheral irritation. Thus the patient, although often suffering intensely from thirst, is filled with such terror by these spasms that he cannot be induced to make any attempt to take fluid.

The disease may be divided into three stages—the prodromal stage, the stage of excitement, and the paralytic stage.

Prodromal Stage.—In the prodromal stage symptoms may or may not be present. In many cases in adults, where the person has been bitten by a dog which is suspected of being rabid, there develops gradually, as a result of apprehension and fear of the disease, intense mental depression. The fear of the disease acts as a constant nightmare, preventing sleep, disturbing all of the functions of the body, causing the patient to relinquish his usual occupation and often to resort to alcohol or narcotics to relieve the mental suffering caused by fear. In some instances the patient may become almost insane from terror even when there is no good reason to believe the animal by which he was bitten was rabid. In other cases the depression does not appear until a few days before the appearance of the disease, and then the patient becomes depressed and melancholy, or nervous, restless, sleepless, and irritable. There may be pain in the scar of the original bite; it may become swollen, tender, and blue; in some instances it is said that the scar opens again and discharges a thin watery fluid, or a papular or vesicular eruption appears round it. Occasionally there are severe shooting pains, beginning in the scar and extending toward the trunk. The patient carefully avoids mentioning the circumstances regarding the bite, makes light of the symptoms, and searches for diversion away from home, or it may be seeks solitude at home. There may be even now some increase in the sensibility of the special senses, light and sound producing discomfort, and the patient may complain of chilliness while the thermometer shows an elevation of temperature of one or two degrees. After a period varying from a few hours to six or eight days the symptoms become more defined and the stage of excitement begins.

Stage of Excitement.—This may be considered as really the beginning of the attack. The first symptoms which arouse suspicion as to the nature of the disease are usually some pain in the muscles of the throat and stiffness or difficulty in swallowing. This difficulty in swallowing rapidly increases, and soon any attempts at deglutition are followed by

violent spasms of the muscles of the pharynx and larynx, and are often associated with or followed by spasms of the respiratory muscles. An intense hyperæsthesia now rapidly develops, both of the nerves of special sense and of general sensibility; the intensity of the muscular spasms increases and the duration of the interval between them diminishes, while at the same time they extend, involving not only the muscles of the pharynx, larynx, and respiration, but, to a less degree, all of the voluntary muscles of the body. At first these paroxysms are brought on only by attempts to swallow, but later the sight of fluids or food, the sound of running water, a ray of bright light, a slight sound, touching the surface of the skin, or *any* afferent impression may serve to excite the paroxysms. During the paroxysms the breathing is greatly embarrassed and painful, and is interrupted by frequent short expiratory efforts; there is great suffering and a sense of impending suffocation. The expression of the face shows most intense anxiety and apprehension. The patient, although suffering intensely from thirst, refuses to attempt to drink, or when the liquid touches his lips draws back in terror because of the recurrence of the spasms. The spasms are of variable duration, lasting from a few seconds to several minutes, and in rare instances death has taken place during a paroxysm from asphyxia. The muscular contractions are of a tetanic character, although opisthotonos does not occur.

At first the mind is unclouded, but later delirium is frequent, and is especially marked during the paroxysms; at such times "the patient may make violent efforts to strike or injure the attendants about him, and cries, howls, strikes or attempts to bite others or himself, until he sinks back exhausted, and remains quiet until aroused by another paroxysm." As a rule, the mind is clear in the interval between the paroxysms. There is a great increase in the secretion of saliva: it is thick and tenacious, and, as the patient cannot swallow it, it drivels from the mouth or he violently attempts to spit it out. The spasms of the muscles of the throat and chest are often associated with the production of a peculiar sound which the imaginative bystanders transform into a bark. It is this that is described when the patient is said to "bark like a dog."

Pyrexia is, as a rule, moderate, although the temperature may go to 104° or 105° F. Vomiting is common, the matter rejected being usually of a greenish-brown color. There may be incontinence of urine and fæces. The urine often contains albumin in large quantity, and there may be casts and blood. Sugar is occasionally present.

The mental delusions are frequently associated in a strange way with animals, and especially dogs, and the mental excitement and fear are strongly increased by the sight of a dog. In children the mental disturbance is commonly less marked, and it bears some relation apparently to the depression and disturbance caused by the fear of the disease which has preceded its advent. The stage of excitement lasts a varying period, from a few hours to eight or ten days. As a rule, however, cases terminate in four or five days.

Paralytic Stage.—A few hours before death the paroxysms become less severe and occur at longer intervals. The patient may be able to swallow and take food without difficulty; the mind may again become clear, but the pulse is rapid and feeble, and the disease soon terminates in death. Occasionally there is more or less complete paralysis, com-

mencing in the muscles of the jaw and involving partially or completely all the muscles of the body (paralytic rabies), and rarely coma occurs. In a few cases, where persons have received very extensive bites from wolves on exposed parts, the disease takes early the form of paralytic rabies. This is also true in a few cases where death has occurred after inoculation according to Pasteur's method. In children the mental symptoms are usually less pronounced, and the disease terminates earlier in death.

Prognosis.—Where the symptoms of true rabies have once developed there is no reason to look for recovery, for, although there have apparently been a few cases which have recovered without treatment or under various modes of treatment, they are of such rare occurrence that they give little reason for hope in any individual case. Nevertheless, the various means of symptomatic treatment recommended should be employed to relieve the severity of the paroxysms.

The percentage of cases in which rabies follows the bites of animals shown to be rabid or supposed to be rabid is variously estimated—from 5 to 60 or 80 per cent. The bites of wolves are most virulent, and next those of cats, foxes, and dogs, in order. Bites on exposed parts are far more likely to be followed by the disease than those upon covered portions of the body, and punctured or greatly lacerated wounds are apparently the most dangerous. Horsley estimates the percentage of cases of hydrophobia following the bites of animals shown to be rabid as about 16. Boulé, however, says that the proportion fixed by Hunter (5 per cent.) approaches nearer the truth. Following bites by wolves the percentage of cases is far higher, varying apparently from 40 to 80 per cent. of those bitten.

Diagnosis.—Great suspicion has been thrown upon the diagnosis in a large proportion of the cases of reported rabies, and much has been written about lyssophobia or pseudo-hydrophobia, the result of fear. Numerous cases have been recorded in which patients apparently suffering from true rabies suddenly recovered when the animal by which they were bitten appeared before them well or when they were convinced in some other way of the absence of rabies in it.

In a well-marked case of rabies there should be no great difficulty in making a diagnosis. No doubt a part of the difficulty usually experienced is due to the extreme rarity of the disease, few physicians in this country having had the opportunity of seeing a single case. By far the most characteristic symptom is the peculiar respiratory spasm caused by attempts to swallow liquids, and where this is present increased significance is given to it by the history of a recent bite. There is rarely some difficulty in differentiating rabies from tetanus and certain forms of organic disease of the brain and insanity, but in true rabies the occurrence of the respiratory spasms with increasing intensity and frequency, the intense hyperæsthesia, and the existence of great mental disturbance —these symptoms followed perhaps by paralysis—make the diagnosis clear. The absence after death of gross lesions sufficient to account for the condition during life increases the certainty of the diagnosis. This may be absolutely confirmed by the inoculation of rabbits with the spinal cord after the subdural method of Pasteur.

Pathological Anatomy.—There is a remarkable variation in the

post-mortem lesions found in different cases of rabies as it occurs in animals. Not infrequently there are no macroscopical changes found after death which are in any way characteristic, but in those cases occurring in dogs, which may be considered most typical, we find that the mucus membrane of the mouth and fauces is greatly congested and covered by a thick, tenacious, mucous or muco-purulent secretion, often mixed with dirt. The mucous membrane of the larynx, trachea, and bronchi may also present similar appearances. The lungs are usually congested, and there may be petechial hemorrhages into the pleura. The heart and the large vessels arising from it are filled with dark blood, completely fluid or containing only soft dark clots. The most characteristic changes are found in the stomach. This is usually filled with all sorts of foreign bodies if the animal has been free, or, if it has been confined, with such as are within reach. In animals which have been running loose, hay and straw, pieces of wood, coal, leather, portions of cloths, stones, sand, earth, and fæces are indiscriminately mixed together, and not infrequently similar contents are found in the small intestines. The large intestine is often empty. The mucous membrane of the stomach and of the small intestines, particularly of the stomach, shows changes quite similar to those found in the throat and larynx, but in a higher degree. The mucous membrane of the stomach is intensely swollen, hyperæmic, filled with extravasations of blood, and may be the seat of numerous erosions. It is covered with a thick, tenacious mucus. The intestinal mucous membrane presents the same appearance in a less degree. The kidneys are commonly swollen, of diminished consistence, and show marked hyperæmia. The bladder is empty, or at most contains a small quantity of cloudy, and it may be albuminous, urine; occasionally the urine contains blood. The mucous membrane of the bladder is also swollen, and sometimes shows petechial hemorrhages into its substance. In the central nervous system there are no characteristic changes visible to the naked eye. As a rule, there is marked hyperæmia of the spinal cord and the medulla and their meninges, and occasionally minute hemorrhages may be found in the floor of the fourth ventricle. The brain and its meninges may also present the same appearances, but these are not constant or characteristic enough to have great significance. Not infrequently, especially in those cases which terminate rapidly, there may be few or no lesions in any way characteristic. The stomach may be empty, and at most the mucous membrane of the respiratory and alimentary tracts appears swollen and somewhat hyperæmic. The intestines may contain no normal products of stomach digestion, and the contents show little or no bile-staining. There may be nothing else abnormal found in the thoracic or abdominal viscera. The brain and spinal cord may present no changes.

In man the post-mortem changes apparent to the naked eye are essentially those of an acute infectious disease, with possibly more marked congestion of the mucous membrane of the alimentary and respiratory tracts, and more marked hyperæmia of the brain and spinal cord and their meninges, than is usually present in other types of infectious disease. It is, however, rather the absence of characteristic changes which is significant in post-mortems on suspicious cases than the presence of any definite gross lesions.

The microscopical findings in the spinal cord and medulla are more characteristic, and assist in the diagnosis of doubtful cases. Sections should be made through the bulb or cervical division of the cord. In these regions there is found microscopically marked hyperæmia, with perivascular foci of embryonic cell infiltration, and little nodules of embryonic cells surrounding degenerated or proliferating nerve-cells. If these nodules are not found, probably the case is not rabies; if found, probably the case is rabies. The nodules are less conspicuous in animals killed in the first stages of rabies than in those which have succumbed to the disease.

We may also find (1) hyperæmia and acute œdema of the meninges, with small hemorrhages around some of the vessels; (2) proliferation of the epithelium of the central cerebro-spinal canal, hemorrhages in the gray matter, and obliteration or thrombosis of some of the small vessels by a hyaline pigmented substance, by leucocytes, or by hyaline degeneration; (3) little foci of degeneration in the gray matter. These foci are often visible to the naked eye.

The lesions of the nerve-cells in special regions are characteristic. They consist in the signs of proliferation, and even in the presence of several small cells in the place of a large one, or in a uniform degeneration. Mononuclear, and rarely polynuclear, cells of lymphatic origin invade the protoplasm of the cell and fill the pericellular lymphatic spaces, dilating them to form nodes (Roux).

When a human being has been bitten by an animal which has been afterward killed, it is advisable, if possible, to make a diagnosis from the autopsy and the microscopical examination of the medulla and cord, so that proper advice may be given regarding the necessity of treatment.

Prophylaxis.—The importance of prevention in any disease is proportionate to its frequency and mortality, and while in hydrophobia, because of its rarity in man, the prevention is seemingly of less importance, yet, because of its almost universally fatal ending, prophylaxis becomes of great moment. As there is positive proof that the disease is the result only of infection, and, in the vast majority of cases, of infection through the bite of a rabid animal, the prevention of hydrophobia in man resolves itself into the prevention of rabies in animals; and experience has shown without question that the disease in animals—in dogs—can be completely stamped out by the efficient enforcement of laws requiring the registration and muzzling of dogs. In Prussia the disease has become practically extinct through such means; in Holland the same is true; and, in fact, in every country, city, or district in which laws requiring the muzzling and registering of dogs have been efficiently enforced the disease has promptly and completely disappeared.

Treatment.—*Preventive.*—In 1885, after a long series of experimental investigations on animals, Pasteur announced the discovery of a method for the prevention of rabies in those who had been bitten by rabid dogs, and in July of that year he first applied the treatment to a human being in the case of a boy named Joseph Meister.

The Pasteur system of treatment depends upon the following observations: (1) the rabic virus is especially present in the medulla and spinal cord of animals dead of rabies; (2) by the successive subdural inoculation of rabbits with an emulsion prepared from the spinal cord

of an animal dead of rabies the incubation period is gradually shortened until it finally becomes fixed at seven or eight days; (3) spinal cords removed from animals that have died after such inoculations, if dried in sterilized jars over potash at a temperature of about 73° F., gradually lose their virulence, and at the end of fourteen days are innocuous when used for the inoculation of animals or men; (4) if an animal or man is inoculated on succeeding days with the spinal cords which have been dried for successively shorter periods, the individuals are gradually rendered insusceptible to the more virulent cords by those of less virulence which were previously used; (5) if these inoculations are made after an individual has been bitten by a rabid dog, protection may be still conferred in the majority of instances, providing too much time has not elapsed between the bite and the beginning of the inoculations.

The formula for the treatment of ordinary bites (not those about the head) is given below:

1st	day,	cord of	14	days in	dose of 3 c.m.	of emulsion.
			13	"	"	"
2d	"	"	12	"	"	"
			11	"	"	"
3d	"	"	10	"	"	"
			9	"	"	"
4th	"	"	8	"	"	"
			7	"	"	"
5th	"	"	6	"	2 c.m.	"
			6	"	"	"
6th	"	"	5	"	"	"
7th	"	"	5	"	"	"
8th	"	"	4	"	"	"
9th	"	"	3	"	1 c.m.	"
10th	"	"	5	"	2 c.m.	"
11th	"	"	5	"	"	"
12th	"	"	4	"	"	"
13th	"	"	4	"	"	"
14th	"	"	3	"	"	"
15th	"	"	3	"	"	"

For bites about the head and face a somewhat intensified method is employed.

From 1886 to 1891, inclusive, nearly 10,000 persons were inoculated in the Pasteur Institute, with the result as shown below:

Year.	Persons treated.	Deaths.	Percentage of mortality.
1886	2671	25	.94
1887	1770	13	.73
1888	1622	9	.55
1889	1830	7	.39
1890	1550	5	.32
1891	1559	4	.25

In these statistics, in the later years the deaths have been excluded when they occurred within fifteen days of the last inoculation, as it was then assumed that the virus introduced by the bite was acting on the central nervous system before immunity had been conferred by the inoculations. There were five cases of this kind in the year 1891, which have been excluded from these statistics.

The cases treated have been divided into three classes: (*a*) persons bitten by dogs in which the existence of rabies was proved by inocula-

tion or by the subsequent occurrence of rabies in another animal; (*b*) persons bitten by animals in which the existence of rabies was confirmed by a veterinary surgeon; (c) persons bitten by animals suspected of having rabies. Roux refers to 710 cases treated in Class *a*, where the bites were on exposed parts about the head, in which only 24 died—a mortality of 3.38 per cent. He declares that the mortality in this class of cases without treatment would be about 80 per cent. It is particularly in those cases in which the bites are upon exposed parts that the mortality is greatest.

Whether we accept as final or not the statistics of the Pasteur Institute as to the efficiency of the treatment, yet it may be safely concluded from the results of the Pasteur inoculations that there is comparatively little danger from the inoculation itself, and that the mortality in persons after treatment bitten by dogs known or suspected to be rabid is far lower than it has ever been before.

Treatment of Bites.—In the immediate treatment of bites from animals supposed to be rabid the main object is the elimination of the poison. If the wound is in an extremity, where the circulation can be controlled, a ligature should be immediately applied, bleeding promoted, the part thoroughly soaked in an antiseptic solution, or, if it is a punctured wound, the wound sucked and the mouth afterward repeatedly washed out with a disinfecting solution; intermittent squeezing and wringing of the part while it is soaked in warm water is an excellent method for promoting bleeding and eliminating the poison. The wound may be opened to its depth and cauterized with actual cautery or with mineral acids or nitrate of silver, or the wound may be excised. The more quickly and completely the poison is eliminated after the bite, the less is the danger from the bite. However, there is good reason to believe that even if the treatment of the wound is not begun until some hours after the wound was inflicted, yet a considerable measure of protection may be thus granted, for it seems probable that the poison may be localized for a considerable period at the point of its introduction; hence in any case where it is thought possible that the wound was inflicted by a rabid animal it should be thoroughly washed and cauterized even if a considerable period has elapsed since the injury.

Therapeutic Treatment.—During the incubation period the psychical treatment is of special importance. Great care should be taken to distract the patient's attention from the subject of the bite, and nothing should be said or done which directs attention to it. The other measures during the period of incubation pertain simply to general hygiene. After symptoms have appeared there is little reason to anticipate anything but a fatal result, and the treatment should be purely symptomatic, and consist in the use of spinal and cerebral sedatives and antispasmodics.

Some observations have recently been reported—particularly by Chantemesse, Tizzoni, Centanni, and Babes—which offer bright hope in the early future of the perfection of a specific means of treatment of hydrophobia through the use of an antitoxine separated from the blood of animals which have been rendered artificially immune to rabies. The observations thus far made, however, are as yet too incomplete to render the measures available for the practical treatment of hydrophobia.

GUNSHOT WOUNDS.

By P. S. CONNER, M. D.

No class of injuries has more occupied the attention of surgeons and surgical writers than those produced by gunshot, and from the study of no other class has greater benefit accrued to the art of surgery in general. But the great changes that in very recent times have been made in weapons, in missiles, and, especially, in the treatment of all wounds, necessitates reconsideration of not a few questions connected with the nature, the care, and the results of these wounds; respecting which much that has been written is now of historic rather than practical value.

As met with in civil life, gunshot wounds are commonly produced by pistol balls or small shot; in military service, by rifle bullets, by large solid shot or shell, or by balls thrown out from case or canister shot. A small proportion of the injuries are caused by caps, by portions of a gun which has burst, or by a splinter of wood or a piece of stone or metal set in motion by impact of a shot.

Missiles.

Small shot vary greatly in size and weight, the extremes being "fine dust," the particles of which weigh less than $\frac{1}{20}$ gr. each, and buckshot of .44 in. diameter and 153 grs. weight. Pistol balls also are of various shapes, sizes, and weights, ranging from a calibre of .22 to .45 of an inch, and a weight of from 25 to 250 grs., all more or less conical, made

Country.	Type.	Calibre, in.	Weight of bullet, grs.	Weight of charge (smokeless), grs.	Bullet-covering.	Muzzle-velocity, feet per second.
Austria	Mannlicher	.315	.244	42	Steel	1968
Belgium	Mauser	.301	.217	38	German silver	1980
Denmark	Krag-Jörgensen	.315	.235	34	Copper	1950
England	Lee-Metford	.303	.215	30	Nickel and copper	2000
France	Lebel	.315	.231	43	Maillechort (alloy of copper, nickel, and zinc)	2073
	Berthier	.301	.231	43	Maillechort	2971
Germany	Mannlicher	.311	.227	42	Steel (plated with alloy of copper and nickel)	2034
Italy	Carcano	.256	.155	32	Maillechort	2329
Japan	Murata	.315	.238	36	Copper	1857
Portugal	Kropatschek	.315	.245	35 (black)	Copper	1984
Russia	Mouzin	.300	.211	35	Maillechort	2000
Spain	Mauser	.295	.245	38	Maillechort	2285
Switzerland	Schmidt	.295	.211	30	Copper or steel	1969
United States, new	Krag-Jörgensen	.300	.220	36	German silver	2000
United States, old	Springfield	.450	.500	70 (black)		1300

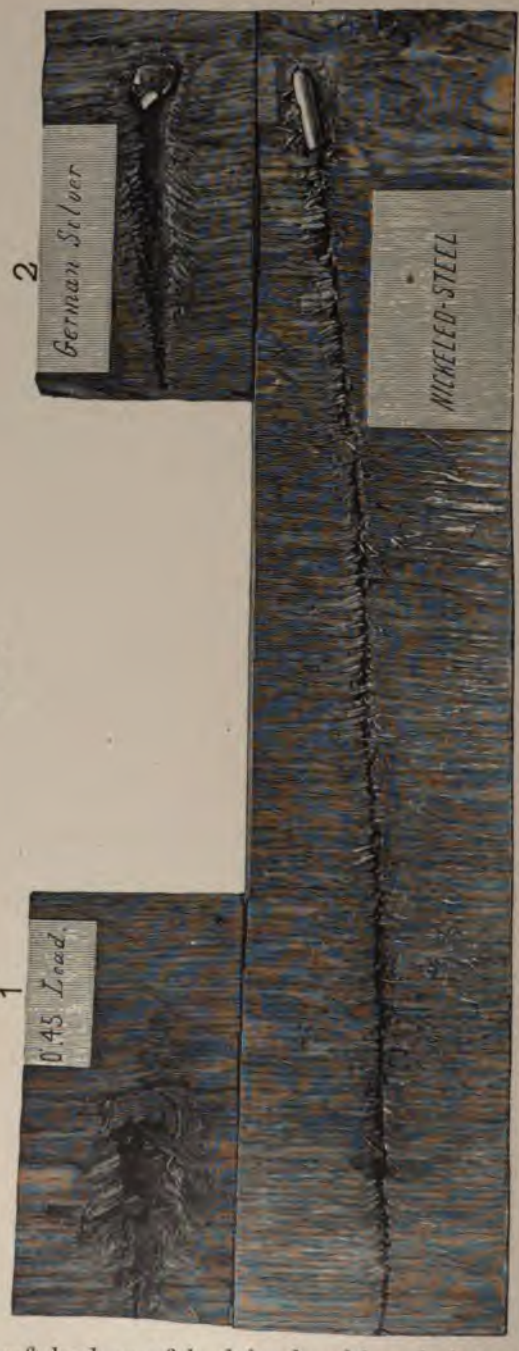


FIG. 14.

Shows the penetration in hard oak, against the grain, three feet from the muzzle, of the following projectiles:

1. .45 calibre, leaden projectile, 500 grains; I. V., 1300 f. s. 3.72
2. .30 calibre, German silver jacketed projectile, weight, 220 grains; I. V., 2000 f. s. 5.73
3. .30 calibre, nickel-steel jacketed projectile, weight, 220 grains; I. V., 2000 f. s. 19.75
The latter was not deformed.

either of soft lead or of lead hardened by admixture of tin from 1 to 40 to 1 to 20 parts. Until recently army bullets were of large size, those employed in our late war varying in calibre from .50 to .71 of an

inch, and in weight from 400 to 760 grs., and even to-day the service bullet of our army has a diameter of .45 in. and a weight of 500 grs. Very soon, however, in common with other nations, we will have a standard rifle of small calibre and a bullet of the modern type, long, slender, cylindro-ogival, of calibre of about .30 in. Made of hardened lead (lead and antimony), the new bullet is covered with a thin jacket of steel, copper, nickel, or an alloy of these metals, with or without zinc addition.[1] To further reduce its weight, it has been proposed to tunnel it from end to end, making of it a sort of punch. The weight of the bullet issued to the European armies varies from 155 to 245 grs., and its length from 3½ to 4 calibres. That the desired momentum may be had, lessened weight is compensated for by increased velocity, 2000 feet or over per second (2971 feet with the Berthier carbine of the French), instead of 1300, as is the case when black powder and the Springfield rifle are used. Because of its swiftness of flight and the increased rotation due to the changed rifling of the piece, the trajectory of one of these bullets is very flat, its range very long, and its penetrating power very great.[2] It is little likely to be deformed, and, especially when steel-mantled, any deformity produced is usually but a slight flattening of the apex. It almost never breaks up, and splitting or stripping off of the jacket in part or whole is rare; particularly so when of steel, copper yielding much more readily. Boring rather than crushing, in very exceptional cases lodging, and then only when near the end of a long flight or after having previously encountered much resistance, these new bullets may be expected to produce lesions in many respects different from those met with heretofore. Experimentally, much has been determined, and the limited experience that has been had in recent wars in Africa, South America, and Asia confirms the results of the experiments made by European and American surgeons[3] upon animals and human cadavers.

General Considerations.—With few exceptions, gunshot wounds are of the lacerated and contused order. According to direction and momentum, the shot may graze or bruise the surface of the body, may enter and lodge, or pass through and out—in other words, contuse, penetrate, or perforate. In proportion as the bullets have been made harder and their velocity increased the likelihood of their lodging in the body has been lessened, so that even in the pistol wounds of civil life perforation is of frequent occurrence, or the bullet is often found to be lodged just under the skin, the elasticity of which has prevented its passing through.

Leaving out of consideration the injuries inflicted within the "zone of explosive action" and affecting bone, that with few exceptions have up to the present time been only experimentally produced, and in which the exit wounds are of very large size, the old-time great difference in the size of the wounds of entrance and exit no longer exists, even when the ball has passed through bone. The diameter of each wound is about that of the bullet; it may be a little smaller, it may be a little larger.

[1] See table at foot of page 445.

[2] The degree of penetration as compared with that of the old bullet is shown by the accompanying figure (Fig. 14), taken from Asst. Surg. La Garde's report to the Surgeon-General of our army.

[3] Delorme, Chavasse, Chauvel, Nimier, Kocher, Bruns, Busch, Reger, Morosow, Tauber, Pawlow, Habart, Horsley, La Garde, and others.

The skin about the wound of entrance is often somewhat depressed, about the wound of exit everted. Both wounds may appear as if made with a punch; that of exit is very often stellate, triangular, or even linear. A narrow dark-colored ring surrounds the opening, especially that of entrance, due not to the heat of the shot, but to the extravasation of blood from vessels of the superficial fascia, which because of its lessened elasticity is somewhat stripped off the skin. As far back as the time of Paré and Maggius it was demonstrated that the shot was not hot enough to ignite gunpowder in sacks into which it had been fired, and could not therefore burn the edges of a wound. When the wound has been inflicted at very close range powder-staining of the parts has been often observed; with the use of metallic cartridges and the improvements in powder manufacture, securing more thorough combustion, such staining is becoming less and less frequent. The distance at which the marking may occur is by no means absolutely determined (as reported, varying between 2 and 10 feet), and cannot be definitely stated because of the variations in the quality of powder used. In some experiments made by Professors Frost and Bartlett of the Dartmouth Medical College three years ago with Winchester-rifle cartridges cal. .44, fired from a revolver, it was found that at 3 feet distance heavy wrapping paper was "perforated with clean

FIG. 15.

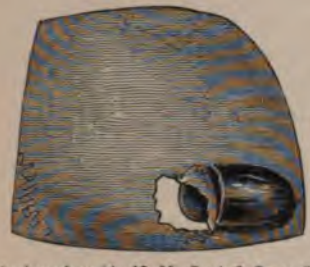
Multiple shot-wounds of arms and back. The opening over the spine was produced by pressure, not by the ball. (Case in Cincinnati Hospital, 1884.)

sharp angular holes in great number. These holes, though less in number at the circumference, extended 1½ feet from the bullet-hole or covered a circle 3 feet in diameter, the bullet-hole being in the centre."

At times the course of the bullet carries it in and out and in and out, giving rise to two, four, six, or more wounds (see Fig. 15), or, if lodgement finally takes place, three, five, etc.

Occasionally it may become a question whether two existing wounds are those of entrance and exit of a single ball or of entrance of two balls, but the answer will likely be found in the position of the openings relative to the line of fire. At times, because of splitting of the bullet,[1]

FIG. 16.



Exterior view (A. M. M., Sect. 1, Spec. 2121).

FIG. 17.

Interior view.

there may be two wounds of exit—a condition which is much less likely of occurrence now than formerly, since the pistol ball is so often of hardened lead, and the mantled rifle bullet will maintain its integrity no matter what it strikes in the body.

In its passage through any tissue the shot commonly destroys outright that which is in front of it, and to a variable distance devitalizes that which surrounds its track. The greater the elasticity of the tissue, the less the direct destruction; *e. g.* the skin may be only split, or the cranium may be pierced and yet but a crack be observed, or even this not be discovered. The gross anatomical structure of the part may greatly limit the destructive action of the bullet, as in a muscle longitudinally traversed, in which the track may be traced with great difficulty or not at all. The area of devitalization varies with the tissue, the size, shape, and velocity of the ball, and the period of flight in which impact occurs. Stated in a general way, it is decidedly less than in former times, the bullets being smaller, less deformed, and having a quicker, steadier flight. In the experiments that have been made it has been noticed that in the early and late portions of their flight—*i. e.* within 300 to 500 yards and beyond 1800 or 2000 yards—the new army bullets destroy as much as, or more than, the bullets previously used, but in the intermediate distances the damage done is markedly less. In part, at least, an explanation of the observed differences may be found in the lateral swing of the ball before its axial rotation is thoroughly established and after its velocity becomes greatly diminished, as in the early and late wabbling of a top, which spins steadily during the middle period of its rotation. So great is the destruction effected in the shorter ranges that these latter constitute a "zone of explosive action," the middle distances belonging to the "zone of penetration," beyond which, near the end of the missile's flight, is the "zone of contusion." The most intense explosive action is seen in wounds of tissues rich in fluid contained

[1] As illustrating the splitting of a bullet, Figs. 16 and 17 are given of specimen in the Army Medical Museum at Washington.

within comparatively unyielding walls, as in lesions of the brain, though such hydrostatic—or, better, hydrodynamic—pressure may be strongly exerted upon the solid viscera of the abdomen, and even upon the hollow viscera when full of fluid or semi-fluid contents.

The course of the ball may be expected to be direct. Deflection of the new army bullet will probably never occur, and as the pistol ball is made harder and the quality of the powder improved, it will become more and more rare to find in civil life a change in the line of direction. Even with the soft-lead conical ball such change is not very likely to happen, and in many cases in which it has been believed to occur the course has been a straight one, the body as it was struck having been put into such position as to give an appearance of deflection.

Much less frequently than before will blood-vessels in the track of the bullet escape injury; but the smaller size of the missile and the diminished cross-section of the area of devitalization must lessen the number of vessels damaged. Nerve-trunks are more likely to be uninjured than the vessels.

As a rule having comparatively few exceptions, the damage done by a bullet is produced in its passage, and when it has come to a state of rest it commonly ceases to do harm, at least when the lodgement is in the soft parts. Though when so located it sometimes changes position because of weight and muscular action, it ordinarily does not, but quickly becomes encapsulated and fixed. In one of the softer viscera, especially the brain, it may produce serious pressure-symptoms either where primarily placed or in some more dependent position to which it has in time gravitated; resting against the wall of a hollow viscus, it may afterward by ulceration reach its interior.

That lodgement has occurred may be inferred with almost absolute certainty when there is present a wound of entrance only. The old-time round ball, even of considerable size, sometimes carried in a piece of clothing, in which it rested as a finger in a glove, and with the withdrawal of such pocket the shot was pulled out; but the bullet of to-day is excessively unlikely to behave in such manner. In a few cases on record the shot has passed out of a natural opening, as in other cases it has entered through such.

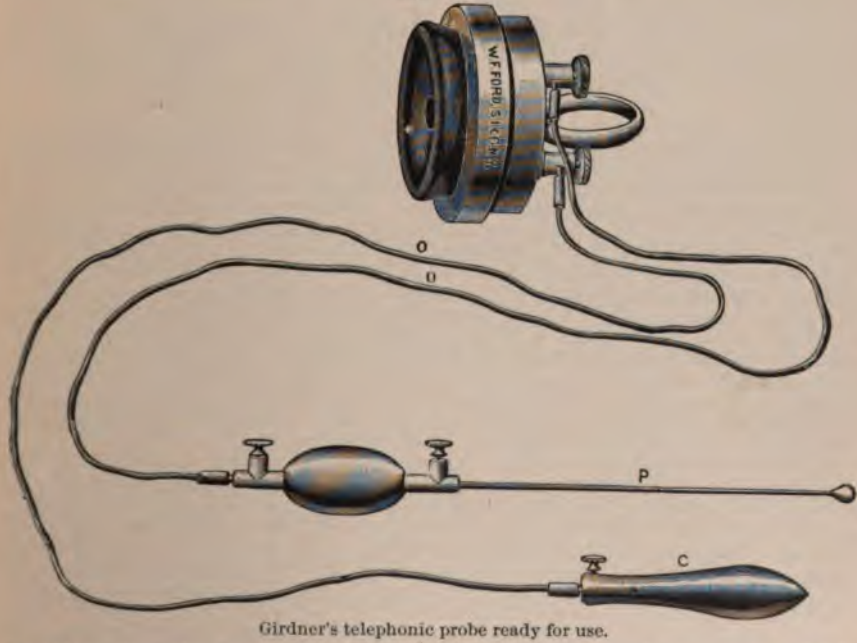
Determination of the position of a bullet may be made by palpation of the injured area or of the surface toward which the shot was tending, by digital exploration of the wound, by probing, and by the use of an electrical apparatus. Very often the desired information will be gained by palpation, and in the wounds of the external soft parts met with in civil life a bullet that cannot be thus located had better be let alone rather than sought for instrumentally. When the track of the ball is large enough to permit of the use of the finger, this best of instruments should be employed, as by it can be well ascertained the nature and extent of the damage done. By it alone can the presence of pieces of clothing be determined. Enlargement with the knife of the wound of entrance and of the track, of which in the past there have been many strong advocates, is certainly not required in cases of pistol-ball injury, and with the new military rifle the wounds in very large proportion will be those of perforation, not penetration. If in any given case there is good reason for believing that a piece (not shreds) of clothing has been carried

in with the ball, careful search for it should be made with the finger, with or without enlargement of the wound according to circumstances. By no probing with a metallic instrument can the presence of cloth be determined, and if left in place it is certain to be a source of infection. Fortunately, the modern conical bullet with its great velocity comparatively rarely carries in with it this septic complicating foreign body.

If a probe is to be used, it should be bulbous-ended and of a diameter but little less than that of the bullet, is best made of aluminum, because of the lightness of this metal, and never should be employed without precedent thorough cleansing. Under no circumstances should a gunshot wound be touched with unclean finger or unclean probe; far better that it should have no treatment at all. The porcelain-tipped probe with which Nélaton's name is so commonly associated, that rubbed against the bullet takes a lead stain, has often proved of value, but not infrequently has failed of accomplishing its purpose, either the surface of the bullet not being exposed or the pressure upon it not sufficiently great.

Of electrical devices to determine the presence and place of a ball, not a few have been presented to the surgical world, some indicating the presence of the missile by deflection of a galvanometer, others by sound. Of these latter the best is the telephonic probe of Girdner. Its employment does not necessitate the use of any battery, as the operating current

FIG. 18.



Girdner's telephonic probe ready for use.

is taken directly from the body of the patient. The instrument, which consists of receiver, wires, bulb, and probe, is thus described by Dr. Girdner.[1] Fig. 18 represents the instrument ready for use.

[1] To each of the binding posts of the receiver attach one end of each of the conducting wires, *O*, *O*. To the free end of one of these wires attach the bulb, *C*, to the

When the aluminum probe is passed into the wound no current is obtained while it touches the flesh, because it is the same metal as the bulb in the mouth, but so soon as this probe touches the leaden bullet the circuit is completed, a current passes, and the fact is announced by a loud clicking in the receiver at the ear. If the probe used was of any other metal than the bulb in the mouth, the current would be established as soon as it touched the flesh in passing into the track of the bullet. Hence it becomes an axiom that the bulb in the mouth and the probe at the end of the other wire must be of the same metal and different from the metal sought for. If this condition is kept in view, any metal, as silver, copper, etc., may be used for the bulb and probe.

"The shafts of the probes are insulated by being enclosed in a fine rubber tube which can be removed for cleansing and replaced. This was found necessary because the end of the probe might fail to touch the bullet, and the shaft touch it some way back from the point, and thus deceive the surgeon as to the exact depth of the missile. It also sometimes happens, where the bullet has entered the cranial cavity, that a piece of the lead is torn off and lodged just within the external wound, while the main portion has penetrated deeper. In such a case, if the shaft were not insulated, all efforts to locate the main body of the missile would be frustrated by the continual responses caused by the shaft of the probe coming in contact with the sliver of lead lying on the side of the track made by the bullet.

"When the telephonic bullet probe is used, there is never any question whether a hard substance felt in a wound is bone or bullet" (Girdner). When the former is touched, nothing is heard "but a

free end of the other attach the probe-handle, and in the slot of the handle place the probe, or needle, you wish to use; be certain all binding posts are tightly screwed and electrical contact perfect at each joint, and the instrument is ready for use.

Place the bulb, *C*, in the patient's mouth—*i. e.* between the teeth and the cheek in the buccal cavity—taking care that the moisture in the mouth makes a perfect electrical contact between bulb and cheek; the operator holds the receiver to his ear with one hand, as when listening in a speaking telephone, while with the other hand he passes the probe, *P*, into the wound in search of the bullet. Nothing will be heard until the probe touches the bullet, when there will be heard a distinct rasping, grating, or clicking sound in the receiver, and you know certainly that the probe has located the missile. The lighter the contact of the probe with the bullet, the louder the sound heard; continuous contact of probe with bullet produces a *continuous* current, and hence no sound in the receiver; the *interrupted* current, produced by making and breaking the contact when the probe is gently passed over the little irregularities on the surface of the bullet, is what produces the sound in the receiver at the ear.

It is well to experiment with the instrument before using it in actual practice, and for that purpose place the bulb in the buccal cavity of an assistant, and after *thoroughly wetting* one of his hands place in that hand a piece of lead large enough to enable him to grasp it firmly; then the operator places the receiver to his ear and probes the lead in the assistant's hand by gently passing the probe over it, and he will find no sound produced in the receiver when the finger-nails or flesh of the hand is touched, but the slightest touch of the probe to the lead causes a grating sound. The hand holding the lead must be *kept wet* or the instrument will not work.

By experimenting in this way the ear becomes trained, so that there is no trouble in determining the presence or absence of a bullet in a wound probed. There is both a steel and an aluminum bulb in the case, and also aluminum probes and steel needles; when an aluminum probe is used, the aluminum bulb must be used on the other wire, but the steel bulb must be used if it is desired to use the needles. The needles are to be thrust through the tissues in searching for the bullet when its course has been so tortuous that it cannot be followed by the probe, or in cases of old gunshot wounds when the missile is still in the tissues and the track made by the bullet has healed.

characteristic clicking or grating when lead is touched and gently rubbed. This sound, once heard, is never forgotten" (Girdner).

Though this and other electric appliances have at times been found of service, their use has been too limited to indicate their real value. As it would seem at present, only exceptionally are they likely to be employed.

Its position having been determined, whether or not the bullet should be extracted will depend upon how much damage will probably be done in searching for and removing it, and the proportion of such danger relative to that consequent upon leaving the ball in place. It may be taken out either through the track of the wound or through a counter-opening, according as the one or the other is most convenient and least harmful, but under no circumstances should the bullet be cut for unless its position has been positively determined.

If cut down upon, care must be taken to fix it firmly while the incision is being made, and that it may be readily removed it must be thoroughly exposed. Its extraction may be effected by the use of a special bullet-forceps (of which that which is long, slender, its blades toothed, and one of them preferably fenestrated and having two short teeth (U. S. Army pattern), will be found most generally serviceable), or it may be caught by any firm-bladed forceps; not seldom an ordinary hæmostatic or sequestrum forceps will prove effective. In the military practice of the future the removal of bullets will doubtless be of exceedingly infrequent occurrence, as only very rarely will the momentum of the shot be so reduced as to permit of lodgement.

The impression has long prevailed that gunshot wounds do not bleed, nor do they, at least those of the soft parts, but exceptionally as they come under care. At the time of the injury hemorrhage does occur, and aside from those shot through the head the majority of the wounded who speedily die do so from loss of blood. But unless a large trunk has been opened the bleeding quickly subsides, natural hæmostasis taking place, and even if it is a large vessel the hemorrhage may not cause early death. During our late war cases were under treatment in hospital in which upon autopsy it was found that the vertebral, carotid, subclavian, axillary, and common iliac arteries, and the internal jugular, internal iliac, and femoral veins, had been opened. There has come under personal observation a case of pistol-shot division of the superficial and deep femoral arteries and the superficial femoral vein, in which death did not occur for ten hours, and one of the left subclavian artery in which it was delayed until the eleventh day. Severe or fatal primary hemorrhage may be expected to be more common in wounds made by the new bullet than it used to be, though it may prove otherwise, since there will be none of the extensive tearing that was often produced by the irregular, deformed, jagged soft-lead ball. Secondary hemorrhage, that formerly was so common and so fatal, will be infrequent in proportion as an aseptic condition of the wound is secured and maintained.

The pain accompanying a gunshot wound is very variable in amount, according to the velocity of the ball, the part injured, and the sensibility of the individual, natural or for the time being. Occasionally acute, it is more generally dull and tingling, the part often feeling as if it had

been struck with a stick. Under high excitement no pain may be experienced for a time, even though the injury is a severe one.

Shock, like pain, is ordinarily experienced by one who has been shot, and is commonly most marked in those whose wounds are of the brain or spinal cord or of parts intimately connected with the solar plexus. It varies in amount from that which is very slight to that which is quickly destructive of life. Its symptoms are often blended with those of collapse; indeed, in the majority of cases the nervous disturbances are largely secondary to the primary disturbance of the circulation. As respects diagnosis and prognosis, the most important of these symptoms is a lowering of the body-heat. After careful observation of fifty cases during the siege of Paris, Redard declared that "a fall of temperature is a constant phenomenon. Every wounded man brought to field hospital presenting a temperature lower than 35.5° C. (about 96° F.) will succumb, and consequently it is useless in such cases to resort to any operation. Every wounded man in whom a salutary reaction does not come on by the end of the fourth hour, and in whom the reaction is not in direct proportion to the fall (of temperature previously), ought to be considered as in a very serious state. Penetrating wounds of the abdomen produce an exceptionally low fall of temperature, which is more marked as the stomach is approached. Wounds by shell, other things being equal, produce a more marked fall of temperature than those by ball."

The ultimate result of a gunshot wound depends upon the size and velocity of the vulnerating body, the parts injured, and the early and after treatment received. Its fatality is consequent upon shock, hemorrhage, and septic infection; the first two being the causes of death occurring quickly, the last that of the great majority, certainly more than two-thirds, of the cases coming under professional care. Due regard to this fact must be had in studying the mortality-rate of any given wound, the statistics that have been accumulated being in large measure those of army practice, of cases not treated aseptically or treated so only in a very limited degree. Recovery from pistol-shot injury is of far more likely occurrence than from a wound made by a service bullet, old or new, the lesion being not so great and the case ordinarily coming under care more speedily.

Shock and primary hemorrhage may be expected to be as great or greater in the wars of the future, in which use will be made of the small-calibre bullet, as in those of the past; but the death-rate of cases coming under treatment will be very greatly reduced if the wounded can be protected from erysipelas, septicæmia, gangrene, and tetanus, all these being infective diseases the causes of which, and the means of preventing which, have in large measure been ascertained only in the last few years and since the time of any great war.

The organisms causing the infection of a shot wound may be introduced on the bullet, carried in on a piece of cloth or other foreign body, be present in the blood extravasated into the damaged area, or introduced upon finger or instrument employed in exploration and treatment.

Rarely will the bullet be the carrier of infection, but the carefully-conducted experiments of La Garde and Messner show that pathogenic organisms are not necessarily destroyed by the heat of the firing—a heat which v. Beck has proved to be much less than is commonly supposed,

the temperature of the recovered steel-jacketed cal. .30 shot being but 78° C., and of the copper-jacketed one 110° C. v. Coler and Schjerning have found that in passing through portions of the human body the temperature of a projectile only in exceptional cases exceeds 95° C.

Infection through the medium of a piece of clothing may be expected to occur as often as such piece is carried in; but the pointed, small-calibre, swift-moving bullet will leave it in the track much less frequently than did the old-time ball. If this is the only infection of the wound, the effect may be but a slight one, and that readily overcome, and if the bit of cloth is not removed or spontaneously extruded, it may be encapsulated and thus rendered harmless.

Germ-laden blood will without doubt be occasionally poured out of the torn vessels to poison the wound-area, but practically this source of infection may be disregarded. In wounds of the intestines a constantly present and potent cause of sepsis is to be found in the contents of the canal.

By far the most common and most important media of infection are the hands and fingers of the surgeon and dresser and the instruments that are introduced into the wound. There was certainly much truth in Nussbaum's declaration that the fate of a wounded man is in the hands of the surgeon who first attends him. In civil practice infection of gunshot lesions other than abdominal is in very large measure due to uncleanly examinations and dressings. It is to abstention from active interference with the wound, either altogether or until it could be done aseptically, and to rigid antiseptic after-treatment, that we are to attribute the generally successful result that has of late years been had in the non-visceral wounds treated in the hospitals of our country, and the much less fatality of wounds of the head, the chest, and the abdomen. How far it may be possible in war to prevent septic infection by primary dressings and later care experience only will determine. The conditions under which the wound is received, the length of time that often must elapse before any assistance can be rendered, the movings that must be made, the hurried dressings that not seldom must be applied—all the unfavorable conditions of field practice—will combine to limit, it may be in high degree, the asepticity that can be secured. On board ship much better opportunity will be afforded to carry out in detail the modern wound-treatment.

Wounds produced by large shot or large fragments of exploded shells as they come under observation are usually very extensively lacerated, even up to complete or nearly complete carrying away of the part struck. At times, as has already been stated, the skin may remain apparently intact though widespread pulpification of muscle and great comminution of bone have taken place. The momentum of even the nearly "spent shot" is sufficient to produce very serious injury, and soldiers have long recognized the danger there is in attempting to stop the progress of a round shot slowly rolling on the ground. Occasionally balls or fragments of several pounds' weight have lodged in the body, even escaping early detection. The only question of interest that is likely to present itself in relation to these severe injuries is whether or not prompt removal of the part shall be done or an attempt made at conservation. When amputation is decided upon, it must be borne in

mind that the muscle-lesion at least is not limited to the part struck; consequently the operation must be done at a level well above that of the wound. In civil practice extensive injury is often produced by a charge of "small shot" at short range acting as a single ball or scattering but little. If the main vessels or nerves of the region are not involved in the destruction, conservative treatment may frequently be successfully adopted, though amputation or (if there is shattering of a joint) exsection, complete or partial, will often be required. In the "small-shot" wounds at a distance of more than a few feet conservatism should be the rule, the lodged shot being removed or left according as their extraction is easy or otherwise. In a limited number of cases serious injury is done by these small missiles, as in the eye, the larynx, or the antero-lateral regions of the neck.

Treatment.—The two most important elements of the treatment in general of these wounds are the prevention of infection and the securing of rest. Bullets may or may not have to be sought for, bone-fragments may or may not have to be removed, torn vessels may or may not have to be tied, but, that prompt repair may take place, every gunshot wound must be made and kept aseptic or so antiseptically treated that suppuration will occur in but a limited degree; and by immobilization, so far as it may be practicable to establish it, the damaged area must be kept quiet. In the majority of pistol wounds, other than those necessarily mortal, when they are treated in the ordinary aseptic and antiseptic way the prognosis is good and repair may be expected to take place promptly. The wounds made by the new bullet will without doubt be found to heal much more quickly than those produced by the old large-calibred, soft-lead bullet. As a rule, the closing of the track commences in its central portion and proceeds thence toward the wounds of entrance and of exit, the former commonly healing last of all. Such closure, especially in lesions of the soft parts, may and frequently does occur without suppuration; more often the pus-formation is slight, and chiefly in and near the entrance wound, and this even though bone has been damaged. It is the recognition of these facts that is leading surgeons more and more to treat at least pistol-ball injuries in the most simple manner, actively interfering with the wounds only when pain, heat, and swelling make it evident that foreign bodies are to be removed or free drainage secured. When, in consequence of small-shot injury of an extremity inflicted at very short range, or of a rifle-ball laceration within the zone of explosive action, or of a crush by a large shot or a large fragment of shell, a limb is very extensively mangled, amputation will generally be required, or, but less often, an exsection. It will, however, doubtless be found that such operations will be much less frequently demanded in the future than they were in former times, just as it is now with cases of extensive compound fractures due to traumatisms other than gunshot.

The primary effects of a gunshot wound (shock, pain, and hemorrhage) are to be treated in the ordinary way. As has already been stated, bleeding in any considerable amount is not of frequent occurrence in the generality of flesh wounds, though a moderate degree of oozing during some hours, or even days, may be expected. Bone wounds are attended with a greater loss of blood, but, as commonly met with

in civil life, the hemorrhage in connection with them does not necessitate any special treatment. In the lesions of the head, chest, and abdomen serious hemorrhage very often is present, and, as we shall see hereafter, in many cases demands prompt operative interference; and the same is true of wounds of the neck, the axilla, and the groin. Where vessels of larger size, arteries or veins, have been torn, recourse must be had to either compression or ligation. Compression often answers a good purpose when properly and methodically applied, more so in cases of vein-wounds than in those of arteries, but when the bleeding is at all profuse the wounded vessel should be freely exposed and tied above and below the point of injury. Chemical styptics—*e. g.* the persalts of iron—should never be employed: again and again they have proved inefficient and their use productive only of evil. If cold (or, much better, hot) water does not stop the bleeding, compression or the ligature should be applied. In a few of the cases in which the main artery and vein of a limb have been simultaneously lacerated amputation may have to be performed to prevent the occurrence of gangrene of the extremity.

Secondary hemorrhage when it takes place (and it may occur at a very late day) will ordinarily necessitate ligation of the vessel—in the wound if possible; if not, well above the level of injury—though at times compression has proved of service, or even the laying open of the wounded part. Whether or not ligation should be done when the vessel is not bleeding has long been a question. There may be no recurrence of the hemorrhage, and the disturbance of the wound necessary to the tying can only increase the gravity of the situation; on the other hand, if ligation is not done, a later bleeding may occur—fatal it may be, certainly adding to the existing danger. As a general rule, the wisest course is not to operate after a first bleeding, but to do so always after a second. There is every reason to believe that in the military practice of the future secondary hemorrhage will be much less frequent than heretofore, due as it is to suppurations and septic processes that can be largely prevented by antiseptic treatment. In civil practice secondary bleeding is of very infrequent occurrence.

Effects upon the Various Tissues.

Skin.—According to the velocity of the bullet and the angle at which it strikes, the skin may be merely grazed, strongly contused, or penetrated. In the former case there will be developed an erythema which will soon subside, or a superficial devitalization may be effected, causing the formation of a thin dry slough, the separation of which will be followed by slight scarring. When the contusion has been more severe, without material injury to the parts beneath, under antiseptic treatment the slough (which may include the entire thickness of the derm) will still be dry, and when its separation takes place it will be found that there has been healing under the crust. In rare instances the elasticity of the skin will prevent its laceration, although the tissues beneath are extensively crushed, as has been observed in certain cases when the part has been brushed by a large shot or massive piece of shell in full flight or struck by such when nearly spent. Not seldom when the ball passes for quite a distance just

under the skin its track will be marked by a deep discoloration of the integument, and the after-separation of the slough will leave a depressed guttered wound, and later a cicatrix.

Fascia.—The formerly often-observed deflection of a ball by a layer of firm deep fascia very rarely occurs when the wound is produced by a pistol shot of to-day, and can never do so when the missile is one of the new army bullets. The fascial fibres being in considerable measure separated rather than torn, some closing in of the openings through the layers may be expected, which may render probing more difficult and drainage less free and complete. It is not likely that surgeons of the future will see, other than very exceptionally, permanent openings with rounded edges in the outer layer of the deep fascia, through which hernial protrusion of muscle can occur—openings that were frequently the result of wounds made by round balls and the earlier-employed large conical bullets.

Muscles.—As made by bullets, except within the zone of explosive action—and there is no such zone with reference to pistol shots—muscle-wounds are not attended with any extensive destruction of tissue, and the associated blood-extravasations are not large. When the shot passes in the line of the muscular fibres there may often be separation rather than destruction, rendering it very difficult, it may be impossible, to follow the track. Passing transversely, though the laceration may be quite great, there is very seldom a complete severing of the muscle. When struck by large shot or a large piece of an exploded shell widespread destruction is effected, with resulting great loss of substance and the after-formation of an extensive and deep scar. Tendons are more often severed, but as a rule a piece is cut out or a perforation made. At times the impact of the shot causes a rupture of the muscular belly above, the tendon itself being only contused. Whether or not the tendon will often be pushed out of the way by the new bullet, and thus escape injury, remains to be seen.

Blood-vessels.—Arteries and veins in the track of the modern bullet, pistol or rifle, especially the latter, will rarely if ever be uninjured. As before, they may be completely or partially divided or may be contused, with liability to the later occurrence of hemorrhage or the formation of an aneurism. Associated perforation of both artery and vein may be followed by the development of an arterio-venous aneurism.

Nerves.—Contrary to what was formerly true, nerve-trunks are less likely to be damaged than the larger blood-vessels. When in the path of the ball they generally, however, are torn or contused, with resulting impairment or entire loss of motion or sensation; pain of greater or less severity and continuance, at times burning (*causalgia*); trophic changes; or absolute destruction of the vitality of the parts to which they are distributed.

Bones and Joints.—Among the more serious lesions met with in military practice are wounds of bones and joints, which constitute about one-fifth to one-fourth of all the injuries coming under care. In civil life the proportionate number is much smaller and their gravity is as a rule much less, caused as they generally are by bullets of less weight and, still more, less velocity.

A bone injured may be either contused or fractured according to the

angle at which it is struck, and, especially, the momentum of the bullet. Contusions produced by pistol balls, more often of course those of small calibre, are frequently of such slight severity (mere jarrings) that their existence is unsuspected or thought probable only because the missile, flattened out it may be, is found resting against the bone. More often, the blow being stronger, some subperiosteal extravasation occurs, and in a limited number of cases the impact of the shot is sufficient to destroy vitality, the necrosed, later separated, piece of bone varying much in thickness.

Musket-ball contusions, which were formerly not uncommon, and were often followed by local and general septic infection, will in all probability be almost or quite unknown in the future, the new rifle bullet fracturing, not bruising, any bone that it may strike. Antiseptically treated, the bone-contusions may be expected to be rapidly recovered from without either permanent thickening or persistent neuralgia resulting.

Fractures are of various kinds, according to the force and angle of impact, the character of the bone struck, and in the long bones the part injured, whether in the shaft or near the extremity. Whatever they may be, they are, in general, due to contact or penetration, the former being mediate or immediate, the result of a tangential or a direct blow; the latter partial or complete, the ball entering and remaining, or passing entirely through to lodge in the soft parts or emerge through the skin. The simplest form of contact-injury is a mere crack, of greater or less length, curving oftentimes at its extremities—a lesion of little moment, very frequently overlooked, and recognizable with great difficulty except upon actual inspection. Percussion, by developing the "cracked-pot" sound, has at times been of diagnostic value, and it may be that evidence of importance may be afforded by the pain in a limited area, which has been shown to be produced by the passage of a galvanic current through a broken bone.

As an exaggeration of this linear fracture there may be a fissure, the edges of the crack separating somewhat, in a superficial bone permitting of recognition of the gap upon palpation. When such fractures are produced by direct stroke, the missile must have in large measure lost its momentum. Rarely, but probably more often than has been supposed, the crack or fissure may extend transversely or obliquely through the entire thickness of the bone, causing the simplest form of a complete fracture, and in a few cases such separation has been found to have occurred not in the area directly injured, but at a level considerably above or below. Because of the absence of muscular traction upon them, or of an incomplete tearing of the periosteum over them, the fragments may remain in apposition, to be perhaps later separated by movements of the part or by muscular contractions after the untorn periosteal bands have softened. These contact-fractures, which, as has already been stated, will often be overlooked, require no special treatment. If protected from infection and the injured area is immobilized, rapid repair will take place.

It is by penetration that the great majority of fractures are produced, the essential character of the injury being a driving in of the part of the bone struck, with or without associated fissures passing out in various

directions and to varying distances (Figs. 19, 20, 21, 22, 23, and 24 are from the report of Asst. Surg. La Garde, U. S. A., *Report of the Surgeon-General of the Army, 1893*).

FIG. 19.

Gunshot injury by the .″30-calibre German silver jacketed projectile, possessed with the velocity usual at 2000 yards.

FIG. 20.

Posterior view.

The central depression may be but slight, even absent altogether when examination is made, having been overcome by the elasticity of the osseous tissue, or the piece of bone may be forced in (to the medullary cavity, for example, in a long bone, or within the cranium in a skull-injury), or it may be completely pulverized and its dust driven out of the body or scattered along the track of the ball, the differences in the condition of the piece directly struck—and they are very wide—depending upon the shape, size, and hardness of the bullet and its velocity. The fissures passing out from the centre of violence are also very variable in number and extent, ranging from a scarcely perceptible crack to a complete breaking up of the bone. When the fracture is in the shaft of a long bone the characteristic fissuring, as Delorme has shown, is that of an elongated × (Figs. 25 and 26), the four primary parts of which may be secondarily split into a few or many pieces. Sometimes the splintering extends into or through the epiphysis; occasionally it ends abruptly

above and below in an almost transverse break, the intervening portion of the shaft being split up into many completely separated wedge-shaped

FIG. 21.

Injury by the .''30-calibre German silver jacketed projectile, with the velocity common at 1200 yards. The orifice of entrance has a punched-out appearance equal in diameter to that of the projectile.

FIG. 22.

Posterior view: fissures are exaggerated by drying.

fragments, such condition being consequent upon an injury at short range. It has long been recognized that the number and size of the fragments

FIG. 23.

Injury by the .''30-calibre German silver jacketed projectile, with the velocity common at 1200 yards.

FIG. 24.

Posterior view.

are in inverse proportion to the velocity of the missile. The sequestra may be entirely detached or partially adherent—*i. e.* primary or second-

ary. In pistol-shot wounds few of them are likely to be found free, and these ordinarily small, and in the wounds made by the new bullet in the middle ranges the fragments are much more largely adherent than they were in the wounds formerly observed. Very frequently pistol balls have force enough only to fracture the bone or to penetrate its substance for a short distance.

When the wound is located in the epiphysis or in the juxta-epiphyseal area, and the injury has not been inflicted at short range, splintering is much less than when it is in the shaft of the bone, a clean perfor-

FIG. 25.

Gunshot injury of the right femur at junction of middle and upper thirds by the .30-calibre German silver jacketed projectile, with the velocity common at 2000 yards (Asst. Surg. La Garde, U. S. A., *loc. cit.*).

FIG. 26.

Posterior view.

ation with little or no associated fissuring being often observed (Figs. 27 and 28).

Almost or quite as clean a perforation may occur at some distance above the articulating extremity, as illustrated by Figs. 29 and 30.

As in the case of wounds of the diaphysis, the ball may remain external to the bone, lodge in it, or pass through it, but, because of the lessened resistance of the cancellous tissue, is more likely to perforate, making a comparatively clean canal, with an outlet wound commonly a little larger than the bullet.

Wounds of the irregular bones much resemble those of the spongy extremities of the long bones, but because of their small size these bones may be expected to be largely splintered, without, however, in many cases, much separation of the fragments.

The flat bones may be extensively shattered or perforated, as is much

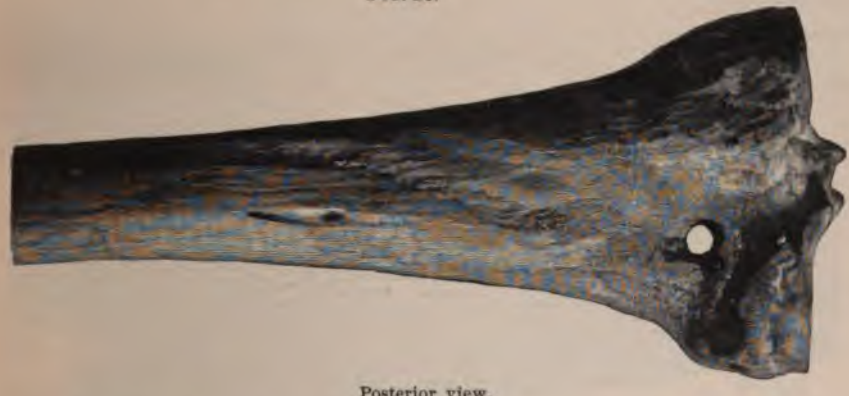
more often the case now than in former times. The perforation will commonly be found to be somewhat conical, its edge on the side of exit being more or less bevelled at the expense of the outer layers. Such perforation may or may not be associated with fissures running for a variable distance into the bone.

Ever since the adoption of the conical bullet military surgeons have observed that there is a marked difference in the damage done to bone according to the range. The destruction produced by a shot at compar-

FIG. 27.

Perforation by the .'30-calibre German silver jacketed projectile, with the velocity common at 1200 yards. The diameter of the track of the bullet in the bone corresponds to the diameter of the missile (Asst. Surg. La Garde, U. S. A., *loc. cit.*).

FIG. 28.

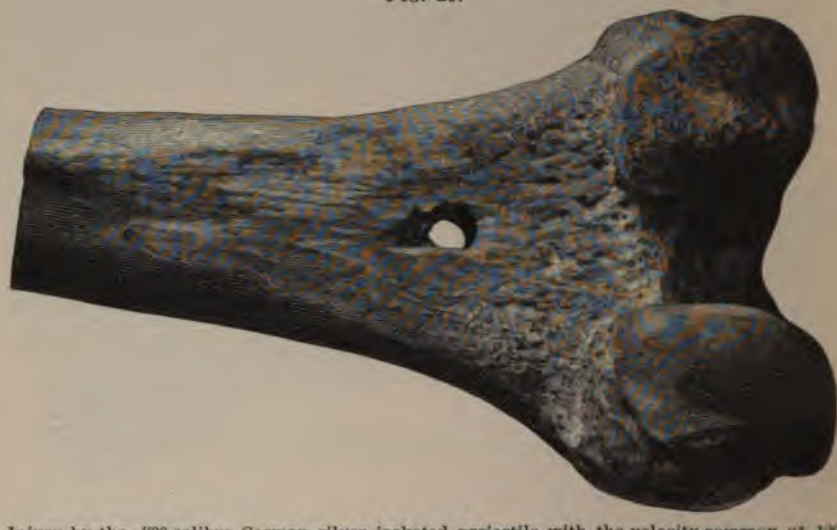


Posterior view.

atively short distance is so enormous that it seems as if the bullet must have been an explosive one, and within such distance has been placed the "zone of explosive action." With the old bullet it extended to 200 to 250 yards, sometimes a little more; with the new it is increased to 350, 400, or even 500 yards. As La Garde (Asst. Surg. U. S. A.) has stated it: "There are no special features, as a rule, to describe about the wounds of entrance, except the appearance at times of bony sand in the tract leading to a fractured bone. When a resistant bone has been hit, the foyer of fracture will show great loss of substance: the bone

will have been driven not only in the direction in which the projectile was travelling, but in all directions, and the pulpification of the soft parts will not be limited only to the track of the bullet, but the utter destruction is noticed some distance into the tissue. The wound of exit

FIG. 29.



Injury by the .''30-calibre German silver jacketed projectile with the velocity common at 1200 yards. The fissure occurred in drying; it was not present in the recent state (Asst. Surg. La Garde, U. S. A., *loc. cit.*).

FIG. 30.

Posterior view.

appears like a bursting forth of the skin; the track leading to the bone is conical in shape, the base of the cone corresponding to the wound of exit in the skin, and the apex to the seat of fracture."

In certain cases the exit wound has been found to have a length of four, six, or even more inches, and a width of three or four, and occasionally bone-fragments driven out have pierced the skin at points outside of the main laceration. No very marked differences have been found to exist between the destructive effects of the old and the new missiles, though doubtless those of the latter are somewhat less. In the wounds produced by pistol balls no explosive action takes place, their momentum not being sufficiently great. Perhaps in small measure due to the swaying of the ball, the axial rotation of which has not become fully settled, practically the immense destruction effected within the zone of explosive action is due to hydraulic pressure, and is proportionate to the fluidity of the tissue struck. At distances outside the zone of explosive action, and up to a range of 1200 to 1500—it may be even 2000—yards, bone-wounds made by the new bullet are of least severity; and it is in this "middle distance" that there occur clean perforations or perforations with the formation of a few though large fragments, and these chiefly, it may be almost wholly, adherent. Beyond a distance of 1500 or 2000 yards comminution and displacement of fragments again become greater,

FIG. 31.

Complete perforation in the upper part of the shaft of the left tibia by the ."30-calibre German silver jacketed projectile, with the velocity common at 1200 yards. There is also an injury in the middle of the shaft by a ."30-calibre projectile at the same range. The bullet struck the crest of the tibia, passing wholly in front of the medullary canal, guttering the crest. There is a complete fracture (Asst. Surg. La Garde, U. S. A., *loc. cit.*).

FIG. 32.

Posterior view.

the result doubtless of the wabbling of the shot; and such smashing of the bone continues up to the extreme range of fracturing.

When it is a ridge or crest of bone that is struck, or the ball crosses a curved surface tangentially, guttering is often produced (Figs. 31 and 32), the notch or furrow being at times quite clean cut, at times associated with fissurings. A ball impinging upon a ridge or crest may be split into two pieces of nearly equal or very unequal size, either entirely

separated or held together at the base. Similar splitting is occasionally found when it is the convex surface of the skull that has been struck. The hardened lead pistol ball is much less likely to be affected in this way than is the soft lead one, and such splitting will not occur, or only exceedingly seldom, when the missile is a jacketed rifle ball.

That fracture by penetration has occurred may or may not be easy of determination. When crepitus is recognized, deformity is present, preternatural mobility exists, and the functional integrity of the limb is lost (in other words, when there are the ordinary symptoms of fracture), there can be no question respecting the diagnosis, particularly so if in addition there are bone-fragments or bone-dust in the track of the ball and the exit wound is of large size. The bone-fragments, if found at all, will be between the bone and the outlet wound, except in injuries within the explosive zone, when at times small fragments are also carried back toward the orifice of entrance. As a general rule, a length of exit wound exceeding an inch indicates that there has been bone-injury; and, as Delorme has shown, a fairly safe conclusion as to whether or not such injury has been received may be drawn from inspection of the exit hole in the clothing, which is very generally larger in cases of fracture than in those of wounds of the soft parts only. But small size of perforation-wounds by no means indicates absence of bone-lesion or its limited extent.[1] Occasionally, in the absence of other signs, perforation is made certain by the presence of evidences of injury of a viscus which could only have been reached after the ball had passed through the overlying bone.

When the symptoms mentioned are wanting and the lesion is rendered likely only because of the direction of the shot, it will often be the wiser course to be content with the establishment of a probable diagnosis, since in the effort to secure certainty the bone-injury may be much aggravated and the after condition of the patient made much worse.

The primary **treatment** must of course vary with the extent of bone-injury. When this is but slight, thorough cleansing of the external wound, and, as far as it may be practicable, of the track, being effected, the part, if the lesion is in an extremity, should be immobilized. If more severe, completely detached fragments should be removed if they

[1] In illustration of the truth of this statement may be quoted a recent report of an experimental case observed by Lt.-Col. Stevenson of the British army, professor of military surgery at Netley. The firing was done at a 50 yards' range. "The bullet passed through the ankle-joint, entering the astragalus behind, above the surface for articulation with the os calcis, and passed out in front through the neck of the bone. The skin-wounds were very small, that of entrance being a little less in diameter than the bullet, and that of exit a little smaller than the former. On dissection it was found that the bullet had passed through the astragalus about half an inch beneath the articulating surface for the tibia. All the astragalus except its head was pulverized, and all its articulating surfaces split except that for the scaphoid. The lower end of the tibia was fissured in many directions, and to a certain extent pulverized, although the bullet had not actually touched any part of this bone. The cause of this condition of the tibia was evidently the bursting apart of the astragalus while firmly held by the grasp of the two malleoli. The attachment of the external malleolus of the fibula to the outer surface of the tibia did not give way, and the internal malleolus was not fractured; thus it was that when the bullet passed through the astragalus, greatly distending that portion of the bone held between the malleoli, the articulating surface of the tibia was split and the lower end of the bone extensively fissured."

can readily be gotten at, the canal drained, the limb immobilized, and antiseptic treatment maintained until healing takes place. Fragments which are adherent should be left in place, after having been as much as possible pressed into position if found to be decidedly tilted off from the normal line of the bone. Not infrequently a sequestrum which is apparently entirely separated is really fastened at one extremity by periosteal bands, and its removal can be accomplished only with difficulty and with resulting increase of damage to the bone. When so fastened it should be treated as an adherent fragment, since if sepsis is prevented its vitality will probably be preserved, and if not it can be extracted later. Until recently the general rule has been to remove an impacted ball, wound-infection being almost certain to occur, and, if the foreign body was left, necrosis of greater or less extent of the bone was quite sure to follow; and now, if the missile can be located and readily taken away, such removal should be made. But if, as is so generally the case in pistol-shot injuries in civil life, to find and remove the bullet necessitates doing much damage to the parts, it had better be left undisturbed. If protected from wound-infection the injured area will generally do well, whether the missile is left or is taken away. When the shot has gone through and out and the crushing has not been very great, as it will not be except at short range, the same general principles of treatment must govern the conduct of the surgeon—removal of separated fragments (and, as has already been stated, they will be found between the bone and the wound of exit), antiseptic cleansing, and dressing and immobilization of the part. When there has been great destruction (as from a rifle ball within the explosive zone, a load of shot from a gun but a few feet away, a large shot, or a shell fragment), whether or not the limb can be saved will depend upon the extent of comminution and the amount of injury done the soft parts. Gunshot fractures, so far as treatment is concerned, do not differ materially from other compound fractures, and if it is possible to employ the same methods of cleansing and dressing, similar good results may be expected. In military practice, from the necessities of the situation, thorough and rigid antiseptic treatment cannot be applied other than exceptionally, but from the limited experience of the last twenty years it may be reasonably hoped that much can be done to lessen the old-time mortality of bone-injuries. In civil life amputation will be required only when the limb has been extensively shattered, and not even then in many cases unless there is an associated laceration of the main vessels or nerves. But on the field, removal of the limb is called for not only when there has been great shattering of bone with or without extensive laceration of the soft parts and injury of vessels and nerves, or when a portion of the extremity has been completely devitalized or has been carried away, but also in less severe cases because of the unhealthy surroundings of the soldier, the existing necessity of transporting him long distances, and the limited attention that it may be possible to afterward give him. Neither in civil nor in military practice should amputation be done when there is a reasonable probability of saving a tolerably useful limb, even though such limb be deformed or the source of some, it may be considerable, discomfort. Often has it happened to surgeons in our country in the last thirty years to see amputation stumps that were painful, frequently

ulcerating, and of little functional value. Formal exsections in the shafts of the long bones, operations "in continuity," should not be done, more of the bone being taken away and the end results being less satisfactory than when there has been an informal removal of non-adherent sequestra.

Later in the progress of the case, as in ordinary compound fractures, removal of the limb may have to be made because of infective processes in the part, suppurations, osteomyelitis acute or chronic, or gangrene. Even under the most rigid antiseptic treatment compression-gangrene necessitating amputation may occur.

JOINT-WOUNDS.

These are either extra- or intra-articular, and, like those of bone, are of greatly varying degrees of intensity. The several joints vary much in liability to injury according to their anatomical position and their exposure to traumatism. As generally stated, in order of frequency are found lesions of the shoulder, knee, elbow, wrist, ankle, hip, though in our late war the wounds of both knee and elbow were more numerous than those of the shoulder.

Extra-articular injuries might well be considered simply as wounds of the soft parts, were it not for the fact that at times, either because of injudicious examinations or more often of extension of septic inflammation, the synovial membrane is opened and the joint involved. A seton wound may be present, or a considerable extent of the coverings of the articulation may be carried away or later destroyed by gangrene. Tendon-sheaths are often opened with or without injury of the tendons, and sometimes because of such openings there is so much discharge of synovia-like fluid as to lead to the erroneous diagnosis of actual penetration of the joint. The old-time round ball occasionally ran around the joint through a large arc, and some have believed that it is not impossible for the conical ball to take a similar curved course: the probabilities are, however, that in the cases in which such wounds have seemed to exist the ball really passed straight from entrance to exit, piercing the joint-cavity, but speedy closure of the middle part of the track occurred and the joint-lesion gave rise to no well-defined symptoms.

Intra-articular wounds may be due to the direct entrance of the ball from without or through one of the bones of the joint, to primary laceration of the synovial membrane in connection with a bone-fissure or later opening by ulceration, or to crushing of the parts by a large shot or a shell fragment. As a rule having few exceptions, a bullet passing through the joint damages one or both of the bones entering into its composition, fissuring, canalizing, grooving, or notching it or them. In the knee it may traverse the upper pouches of the synovial membrane without causing osseous lesion, or if the leg is somewhat flexed upon the thigh (at an angle of from 150° to 170°), it may pass from side to side below the patella without impinging upon either femur or tibia.

That a joint has been injured may be readily determined when there has been extensive laceration; when upon palpation much comminution is found to exist; when great fulness of the synovial cavity is rapidly

developed, showing that there has been a large extravasation of blood into the joint; when there is free discharge of mingled blood and synovia from the wound of entrance or of exit or from both; or when bone-dust or fragments are found in the exit wound. But when none of these symptoms are present the diagnosis must rest upon impairment of function, upon escape of synovia, and upon the position of the wounds of entrance and exit with reference to the articulation. Inability to use the limb has little or no significance, as it may be and often is associated with an extra-articular injury. Escape of synovia in limited amount may be from an opened tendon-sheath. Of much greater value is the direction of the line joining the wounds, for it may be very confidently assumed that when this line leads through the joint a conical ball, pistol or rifle, has gone through the articulation. In the knee and elbow, less often at the ankle, by digital pressure crepitus and yielding of fragments may frequently be detected. The appearance of the wound gives no sure indication of the condition of the parts within. As has been truly said, "that which more than everything else characterizes these injuries is the insignificant lesion of the fibrous and cutaneous envelopes, concealing damage, often very considerable, of the ends of the bones." Probing in doubtful cases should not be resorted to, for it may open a previously intact capsule. Accuracy of diagnosis is not necessary in such cases, the wound being regarded as an articular one and treated accordingly in a conservative way. When the bullet has passed through the epiphysis the splintering is likely to be confined to it; when through the juxta-epiphyseal area it will probably affect both the epiphysis and the lower part of the diaphysis. The fissuring at times is both radiating and circular. The experiments made with the new bullet show that in the middle ranges canalization with little or no splintering will often be produced, especially in those articular extremities that contain much cancellous tissue. Commonly the sequestra are few and but little displaced. Within the zone of explosive action great destruction is effected. In a limited number of cases there are complicating lesions of large vessels or nerves, as also at times of the chest and abdomen, in injuries of the shoulder and hip.

The **prognosis** in these joint-wounds has always been grave, even in the accidents of civil life. The average mortality of the cases tabulated by Longmore was 32.25 per cent., and of those occurring during our late war 33.58 per cent., and as respects the various articulations ranged from 12.9 per cent. in wounds of the wrist to 85 per cent. in those of the hip. But these are the death-rates of cases not protected by the treatment of to-day against the septic infections, and to such infections from three-quarters to nine-tenths of the mortality has been due. It cannot but be that in future wars, however defective the wound-dressings may be because of the conditions necessarily associated with field service, there will be a saving of a much increased proportion of those shot through the articulations. In civil practice the probabilities of recovery are now great, and a fatal result of an uncomplicated joint-wound is not to be expected.

Heretofore, in cases that have not died and in which amputation has not been done, the functional value of the preserved limb has usually been far from very good. Ankylosis, either true or false, to a greater or

less extent, has been present in the large majority, the fixation often being angular and deforming; frequently chronic osteomyelitis, with consequent bone-fistulæ, has been observed; dangle-joints have followed many of the extensive resections; and an irritable neuralgic condition of the damaged part, lasting for years or during the whole after-life of the wounded man, has often been experienced. Here, again, it is to be hoped—indeed, expected—that the future will be better than the past, since in no small measure the difficulties mentioned have been due to, or at least much aggravated by, suppurative inflammations. Protected from such, it has more than once been shown that even lodgement of a foreign body—*e. g.* a bullet—in the articulation may not prevent recovery with free mobility of the joint.

The **treatment** of joint-wounds is either by expectancy, by excision, or by amputation. Expectancy, which includes removal of foreign bodies (bullets, free sequestra, etc.), is a method of treatment, as we will see later when considering the lesions of special joints, the adoption of which in the past was at the risk of great danger to part and life in wounds of other than very minor gravity. Suppurations, necroses, general infective diseases, either death or late amputation,—such was too often the record in the cases of articular injuries treated conservatively; but as it is now possible in wounds in civil life to prevent the development of morbid processes consequent upon the action of pyogenic organisms, either wholly or in great measure, rarely should any other than conservative treatment be adopted—never, except when there has been such destruction of the joint and parts about as to make it impossible to save the limb, or to save it with reasonable expectation of its being serviceable. Not even the laceration of the main vessels or nerves absolutely compels primary amputation.

In a rigidly antiseptic way loose fragments of bone and pieces of cloth should be removed, and the bullet also if it has lodged and the size of the canal permits of its being readily reached and extracted. Commonly, the diameter of the track is small and the bullet is firmly fixed in position, so that more harm will likely be done in finding the ball and taking it away than by the missile itself if left undisturbed. The wound and the skin about the orifice of entrance and exit having been thoroughly cleansed, the limb should be antiseptically dressed and immobilized in the same manner as in the case of an articular traumatism other than gunshot. If largely distended with blood, the joint should be aspirated. The effort to render the wound aseptic and to maintain it so failing, the resulting suppurative inflammation will ordinarily be of limited extent and is to be treated in the usual manner.

Though experience only, and that the large one of a great war, will definitely settle the question, there is every probability that the joint-wounds produced by the new small-calibred bullet will in large measure be safely and satisfactorily treated expectantly; and bullet wounds will be, as they always have been, the great majority of articular lesions.[1] Septic arthritis, when it arises, is to be treated by free incisions, thorough cleansing, and the maintenance of full drainage. Formerly common, it will doubtless hereafter be developed in but a limited number of cases,

[1] In our late war they were about 87 per cent.; in the last three Prussian wars, 93 per cent.; 94.5 per cent. in that of 1870–71.

those in which either the primary disinfection of the wound has been defective or the after-treatment has failed of preventing the occurrence of suppuration or infective osteomyelitis. If upon opening up the articulation extensive destruction of bone is found to exist, amputation or excision should be resorted to, though the probability of recovery is not very great.

The extreme fatality of lesions of the major articulations treated expectantly during the wars of the first half of this century led to the establishment of the rule that in such injuries amputation or, much less often, excision should be done—a rule very generally observed during the wars of the third quarter, though removal of the damaged part, rather than of the limb, was more freely resorted to, especially in wounds of the shoulder and elbow. Even under such treatment the mortality-rate was high, 33.5 per cent. of the joint-wounds in our late war terminating fatally, chiefly because of septic infection.

In all probability, in the future amputation will be done only when there has been extensive crushing of the joint and parts about, or the articular wound is complicated by such vessel- or nerve-injury as to prevent the preservation of the vitality of the limb. Excision (which dates back to the time of Moreau and Percy) will be done but seldom, not because of its fatality, for that will be greatly reduced (it is now only about one-eighth of what it was in pre-aseptic times), but because the end-result of the operation is not so good as that following conservative treatment. Gurlt, having studied the after-history of 652 soldiers upon whom resections had been done during the late German wars, found that there was good functional use of the limb in less than 37 per cent. of the cases; limited use, and that often only when prothetic apparatus was employed, in 50 per cent.; and in more than 13 per cent. the limb was useless, or worse, a burden. It is much to be regretted that no one has in a similar manner determined and reported the end-results of the 1346 cases of excision of one or other of the six larger joints during our late war which are known to have recovered from the operation. Were it possible to operate subperiosteally, such regeneration might be expected as would materially increase the functional value otherwise secured, but in a primary operation for gunshot injury only very exceptionally can the periosteum be saved, and the attempt to do so is almost always but a waste of time.

Wounds of Special Joints.

Shoulder.—About 2 per cent. of all wounds received in action are of this articulation, and about one-sixth of all the articular lesions. The injury is almost always one of penetration, the ball either striking the joint or fracturing the humerus, and, through splintering, opening the synovial cavity. In war the left joint is more often wounded than the right, because of its advanced position in infantry firing. With cavalrymen the reverse is true, the right shoulder being carried forward in the use of the sabre or pistol. The degree of injury caused by the new bullet, except at short range, will doubtless prove to be decidedly less than by the old, canalization being largely effected, with but a moderate amount of associated splintering and much less separation of the fragments. Lodgement of the bullet, occasionally observed heretofore, is

not to be expected; even in the pistol wounds of civil life the ball rarely fails to perforate. Determination of the part of the humerus struck, whether head or neck, anatomical or surgical, must rest usually upon the positions of the wounds of entrance and of exit, and is really a matter of very little importance. That a fracture of any kind has occurred will often be known only from the direction of the shot, the fragments being so held together that neither crepitus, preternatural mobility, nor deformity can be discovered.

The **prognosis** may now be regarded as very good in cases uncomplicated with lesions of the larger vessels or nerves or of the chest, and in individuals whose personal condition and hygienic surroundings are not bad. Formerly it was otherwise; the mortality-rate during our war was 34 per cent. But statistics of date prior to twenty years ago have only an historic value.

The **treatment** in civil life is by expectancy, and doubtless will be so hereafter in army practice. Amputation will be reserved for cases of extensive crushing and of associated laceration of the important structures in the axilla. Even in these last conservatism will be largely employed in non-military traumatisms. When both scapula and clavicle are injured, as well as the humerus, it may at times be advisable to amputate high up, doing an interscapulo-thoracic operation after the method of Berger.

Excision, which was so much favored and so extensively practised in the ten years between 1861 and 1871, will rarely be employed, for it has proved, as observed in our own country and in Germany, that the late condition of the great majority of those thus operated upon is far from being satisfactory,[1] and a more useful limb may reasonably be expected to be secured by conservative treatment. Moreover, so far as we may infer from the experience of our late war, excision is more dangerous than either conservatism or amputation (36.6 per cent.; 27.5 per cent.; 29.1 per cent.), and, though the present wound-treatment will greatly reduce the mortality-rate, the reduction must apply equally to the three methods of treatment.

ELBOW.—These injuries, which constitute about one-tenth of the wounds of the upper extremity, are occasionally periarticular, but very generally perforative, the missile rarely lodging. In a few instances the capsule has been opened without any bone-lesion being produced, usually when the forearm is somewhat flexed and the ball has passed just above the olecranon.

The extra-articular wounds, properly treated, are of importance only as there is serious nerve-injury or because of hemorrhage.

As in other articular lesions, the extent of damage to the bones varies within wide limits, but in a large proportion of the cases as now met with comminution is not great, and the fragments are chiefly, it may be entirely, held in close relation with each other. The humerus, the ulna, or the radius may be wounded, or any two of them, or all three in the

[1] In 213 cases Gurlt found that there were but 4 in which the functional value of the limb was very satisfactory (1.87 per cent.), 90 in which it was good (42.25 per cent.), and in 119 it was either bad or very bad (55.88 per cent.). After conservatism in former times an ankylosed shoulder was usually present (in seven-eighths of the cases, according to Chenu); after excision there was often a dangle-joint.

extensive crushings of the joint. The lesion of the humerus may be confined to an epicondyle, may affect only the articulating surface below the epiphyseal line, or may be located in or just above that line. At the present time it may be expected to be less extensive than formerly, when the soft-lead, large-calibre ball was used, an illustration of the destructive action of which is given in Fig. 33.

FIG. 33.

Shot perforation of right humerus (A. M. M., Spec. 4109).

As a rule, the precise character of the injury can be determined only with difficulty, except so far as it is indicated by the direction of the line joining the wounds of entrance and exit. Equally as a rule, such determination is of little practical value. The complicating injuries are of the arteries, usually the brachial, and of the nerves, the ulnar being much more often the one wounded. Because of the nerve-lesions there may be disturbance of sensation (hyperæsthesia or anæsthesia) or impairment of motion of the hand and fingers.

When the joint-wound is due to pistol shot the probabilities are very great that the limb can be saved, and that with considerable, it may be quite perfect, after-usefulness; and the same will doubtless prove to be largely true in the injuries caused by the new missile, except those received within the explosive zone. Associated wounds of the brachial artery and the median and musculo-spiral nerves have long been held to necessitate amputation, but by ligation of the vessel and rigid antiseptic treatment it will doubtless be possible at times to save the arm, though its functional value will be much impaired. In the crushings by large shot and in the extensive lacerations produced by small shot at short range amputation will ordinarily have to be performed. Occasionally the operation may be done at the joint, but commonly the damage to the soft parts will be such as to necessitate removal higher up. Heretofore the mortality-rate of such operations has been greater than that of amputation through the middle of the arm or above that level (20.70 per cent. as against 12.30 per cent., or 13.67 per cent. as given by Otis), but probably not only the actual but the relative death-rate will be much lowered under antiseptic treatment, particularly so if, as has been thought, the greater mortality of operations in the lower third has been due to unnoticed fissures extending above the level at which the removal is made, through which fissures pyogenic organisms have entered the bone.

In the great majority of cases these wounds should be treated expectantly, by immobilization, and with the most thorough antisepsis.

The result may be expected to be not only better than that following operative interference, but much better than that heretofore secured—fewer ankyloses, less impairment of the motions of the hand and fingers, and much more perfect use of the preserved joint. It is not likely that under the present method of dressing from first to last a future investigator will find, as did Dominick after the Franco-German War, that in 163 cases there was complete ankylosis in 82.8 per cent., incomplete in 11 per cent., and free mobility in but 6.2 per cent.

Amputation, as has already been stated, is indicated only when there has been great injury to both bones and soft parts. Excision, which

done for disease is highly successful, and which was extensively tried in the late wars in our country and in Europe, is not now regarded with favor by the great majority of surgeons. Its mortality-rate in pre-aseptic days was from 20 to 25 per cent., and that whether the operation was partial or complete, and the end-result was not good in about 75 per cent. of those who recovered. Gurlt's statistics show that in 44.3 per cent. there was ankylosis of the elbow, and in 36.2 per cent. abnormal mobility, and in only 32 per cent. was the usefulness of the hand preserved. Of course much of the after-difficulty was due to inflammations and suppurations which can now be prevented, and further experience may show that excision is a better operation than it is to-day believed to be.

WRIST.—This injury, which is not very common and is often in association with lesion of the lower ends of the radius and ulna above and of the second row of the carpus and the metacarpus below, is more frequently met with on the left than on the right side. When the bullet passes antero-posteriorly, much less damage is done than when its course is from side to side. Neither the pistol ball nor the small-calibred bullet of to-day is likely to do anything like as much harm as was done by the old .45, .50, or .55 calibre soft-lead bullet, except when fired at close range. Associated injury of tendons, bursæ, nerves, and vessels, one or all, is frequent, and much of the gravity of the lesion in former times was due to suppurative inflammation of the tendon-sheaths and of the palmar bursa, by contiguity led up along the fascial planes of the forearm. To such septic inflammations and those of the damaged bones was due almost entirely the general mortality-rate of these wrist-wounds—during our late war 12.9 per cent., and in the Franco-German War 12 per cent.

The **prognosis**, therefore, at the present day must be greatly more favorable; it certainly is so in the wounds of the joint that commonly come under care in private practice.

The **treatment** should be expectant, except when the laceration is so very extensive as to necessitate primary amputation. Formal excision should not be done; the mortality attending it during our war was more than twice that after conservative treatment (15.6 against 7.67 per cent.); in only 3 out of 72 cases were the results in "any way good" (Gurlt); of 16 German patients, but one had a good arm and hand; eight times the parts were but tolerably useful; six times they were bad; and once the forearm and hand were worse than useless: well might Gurlt say that the results were "very unfavorable." Removal of the lower end of either radius or ulna alone was almost certain to be followed by lateral deflection of the hand even to a right angle. The ankylosis, deformities, and impaired finger-movements that so generally followed conservative treatment also in the past will do so in much less degree in any future war, when wounds will be rendered and kept in some measure at least free from infection, immobilization of the forearm and hand secured, and methodical movements of the fingers duly made.

HIP.—Wounds of this joint are of infrequent occurrence, being but from one and a half to three in the thousand of all gunshot injuries, yet are of extreme importance, "pre-eminently hazardous to life, obscure in diagnosis, and difficult in treatment" (Huntington).

In about one-eighth of the cases in our war the lesion was periarticular

(49–386), the capsule, however, being probably opened in a considerable proportion of them. The diagnosis of such injuries often remains uncertain, and prognosis is grave or otherwise according as there are or are not serious complicating wounds of vessels, nerves, or the abdominal organs, or (and this is one of their chief dangers) as septic joint-inflammation is or is not secondarily developed. Of the 49 cases in our war, 21 proved fatal. Uncomplicated, their treatment is that of flesh-wounds in general, except in those cases in which a trochanter is guttered or perforated without fissuring into the neck, and then it is that of ordinary bone-injuries of like character.

An articular lesion may be of the neck, the head of the femur, or of the acetabulum, or of two or all combined. That it has occurred when the vulnerating body is a bullet which has made the usual narrow track—and this is the more common condition—may be indicated by free discharge of bloody synovia or by the usual symptoms of fracture; but in a large number of cases its determination must rest on the line of direction of the ball, the bone-fragments being mainly held in place, and those which are detached being at such depth in and around the capsule as not to be discovered except upon free opening up of the joint. Even though extensive fissuring be present, the wounded man may yet be able to stand upon the limb and walk, occasionally for several days. Twelve such cases are reported by Deininger. The results in all past wars have been exceedingly bad: in the French army in the Crimea the mortality-rate was 93⅓ per cent.; in our war, 84.7 per cent.; in the German army in 1870–71, 77.9 per cent. In civil life the injury is very rare and often associated with grave vessel or visceral wound; the chances of recovery, when it occurs, are of course better than in military practice, but still far from being good.

The fatality in cases ending quickly is due to shock, which is great, to hemorrhage from large vessels in the vicinity of the joint, or to associated abdominal wounds; in those living some days it is due almost entirely to septic infection. The lethal influence of shock will be much as it has been; that of hemorrhage may be expected to be somewhat lessened, as ligations may be done with much less danger of after-suppurations and secondary hemorrhage; that of wound-infection will be removed in great measure in civil, in considerable measure certainly in army practice.

Treatment is, as in other joint-lesions, conservative or operative. Much more largely than heretofore will it be by expectancy. Never again, in all probability, will its mortality-rate be anything like so frightful as in our war (98.87 per cent.), when those who lived beyond the first few days with scarcely an exception died of suppurative inflammation of the joint and the structures around; nor that of the war of 1870 (75 per cent., Deininger; 71.59 per cent., Langenbeck). Gunshot groovings and perforations antiseptically treated, well immobilized, with the parts maintained in proper position by extension, should unite much as do the ordinary fractures of the hip; and there is every reason to believe that they will. If required, arthrotomy for the removal of loose fragments or the disinfection and drainage of the joint, or late formal resection, may be done with a fair prospect of a favorable termination of the case. Primary exsection rarely need be performed, and

in the absence of septic inflammation and suppuration there will be no such danger in operating after a few days or weeks as there was formerly, when the so-called intermediary and secondary resections were done.[1] In a word, though probably excision, which was first done by Oppenheim in 1829, will seldom be required, its results will be much better, and quite a considerable proportion of those operated upon will be able, as a very few heretofore have been, to stand and walk with much freedom and but little fatigue. The operation may be done either through one of the ordinary posterior incisions or through the anterior incision of Hueter, according to the part of the bone most extensively damaged.

Amputation, originally performed by Larrey in 1793, will be reserved for those cases in which the destruction of the bone and the adjacent soft parts has been very great, those in which the femoral vessels (arteries and veins) have been damaged, and as a late operation when the condition of the parts that have been treated expectantly or even by excision is such as to make it evident that the limb cannot be saved, or if saved that it will be of little value. As has been stated of the other methods of treatment, the adoption of this will in the future be followed by better results than in the past, and for the same reasons, though shock and hemorrhage must still exercise a very grave influence; and it was chiefly to these that we must attribute the death within twelve hours of 16 out of the 22 cases that died after primary amputations done during our war. Hemorrhage at the time of the operation may now be very thoroughly controlled by the use of long pins (as in the method of Wyeth), or, if the character of the wound forbids their use, by amputating through the thigh and later extracting the bone above after a method like that of Furneaux Jordan. Historically, it is a matter of much interest to know that the mortality-rate of all the amputations at the hip-joint during our late war, 66 in number, was 83.3 per cent.—88 primary, 100 intermediary, 55.5 secondary; in the war of 1870–71, 100 per cent; in all the wars of the century up to the close of the Franco-German War, as published in the *Medical and Surgical History of the War of the Rebellion* (250 cases), 89.1 per cent.

KNEE.—The exposed position of this joint renders it very liable to be injured, the lesion being articular in about nine-tenths of the cases.

When periarticular, it is most often behind the joint in the popliteal space, and, aside from septic complications, is dangerous only in proportion to the injury done the vessels and nerves. Wounded vessels being tied and antiseptic dressings applied, with immobilization of the limb, recovery may be expected to follow, the leg and foot, however, not seldom being seriously damaged functionally on account of nerve-lesion. Under the old method of treatment secondary hemorrhage often occurred, and at times gangrene from thrombosis of the contused popliteal artery or vein. Removal of the limb can be required only when the injury to the parts has been very extensive. Of the 351 cases

[1] In our late war the mortality-rate of primary excision was 96.9 per cent., intermediary 90.9, secondary 72.7; Langenbeck's statistics show 100 per cent. of deaths after primary and intermediary, and 75 per cent. after secondary operations, and Gurlt's 100 per cent. after primary, 85.7 after intermediary, and 93.7 after secondary.

observed in our war, 27.9 per cent. died, the mortality-rate of the 313 cases treated conservatively being 22 per cent.

Of the articular wounds a few are without bone-injury, the shot passing through the upper synovial pouch or across the front of the joint in flexion. A few (about 1 per cent. during our war) are of contusion only, but the great majority are of fracture, the patella alone being damaged in somewhat less than 10 per cent. The ball may come into the joint through the femur or tibia, or the bone-lesions may be secondary to the piercing of the capsule. The cavity may be opened at once by cracks running from the track of a ball that has penetrated or more often perforated the condyle, or secondarily because of septic bone-inflammation. If the bullet has passed through the bone into the joint, the incrusting cartilage may be largely destroyed or only split open, the slit-like wound rapidly closing.

All the characteristic symptoms of joint-injury are here manifested in high degree, and in pre-aseptic days septic inflammations (osteomyelitis, arthritis, periarthritis) were almost absolutely certain to be rapidly developed. Associated wounds of the popliteal vessels and nerves are at times present.

Prior to 1876 the **prognosis** of these knee-fractures was very grave, death occurring in more than two-thirds of the cases. In the Crimean War, according to Longmore, not a man recovered except after amputation, and nine-tenths of those operated upon died. In our war the mortality-rate of the 3355 cases reported was 53.65 per cent., and of these cases 283 were of injury of the patella only. But, beginning with the cases treated by v. Bergmann and Reyher, the results of the comparatively few injuries observed in recent years have been greatly more encouraging. Protected from infection, there is no good reason why the mortality-rate should not be very much lowered, especially in the injuries observed in civil practice, which, comparatively, are not severe.

As with the other joints, so here: three methods of treatment are before the surgeon from which to choose—expectancy, amputation, excision; and, as is true of the other joints, the knee may now in the great majority of cases be treated most satisfactorily by the first. Selection of method is not to be determined by consideration of statistics. It matters little that under conservative treatment the American mortality was 60.6 per cent.; that of 1866, 43.5; that of 1870–71, 48.1 (German), 59.7 (French); that of 1877, 28.3; that after amputation the death-rate in 1861–65 was 53.6 per cent. when the removal was through the lower third of the femur, 56.6 when at the knee-joint; that excision terminated fatally with us in 81.4 per cent. of the cases, in 1864 in 85.7 per cent., in 1866 in 86.6, in 1870–71 in 80, in 1876–77 in 100 per cent. These figures have now but an historic value; the conditions under which treatment by any method is carried out are materially changed.

When the injury is other than a very extensive one conservatism should be employed; when the limb evidently cannot be saved it should be taken off. What is to be the place of excision in the future remains to be determined. The operation in civil life for pathological conditions and for ordinary traumatisms (in the few cases in which it has been

employed) has been so free from risk to life, and so satisfactory in its end-result, that it is quite probable that where the surroundings are favorable and the patient need not be moved, excision will at times, perhaps often, be done. After this operation, and especially in the cases treated expectantly, the functional value of the part will hereafter be much greater than heretofore, since the ankyloses will be fewer and the periarticular thickenings and adhesions decidedly less. During the course of treatment constant care must be taken to prevent, or at least to limit as much as possible, angular deformity.

ANKLE.—Wounds of the foot and of the lower part of the leg involving the ankle-joint have been often observed in time of war, this articulation being the fourth of the six larger joints in order of frequency of damage, and occasionally, though rarely, such lesions are met with in civil life.

The periarticular injuries, which constitute but a very small minority of the cases coming under care, are of more than ordinary interest because of the frequency of tendon-lesions, with their associated danger of suppurations running up along their sheaths, and of the later restriction of movements of the ankle and foot. Division of the anterior or posterior tibial artery necessitates ligation.

Unless produced at short range, wounds of the bones of the joint by pistol balls or the small-calibred bullet are not ordinarily attended with such comminution as to compel operation. Quite often the fragments will be found so little displaced that no positive evidence of fracture can be secured by either pressure or warrantable movement of the foot upon the leg, and, as a considerable amount of synovia may be discharged from the opened tendon-sheaths, the diagnosis must be but a probable one based upon the course of the missile. Even this may not in pistol wounds be apparent, because of lodgement of the bullet, which occurs in an exceptionally large number of cases as compared with the lesions of other joints. The new bullet will almost certainly pass through and out.

Formerly the mortality-rate was quite high (26 per cent. in our war), but antiseptically treated these injuries should be recovered from in very large measure. Of 24 Austrians wounded in Bosnia, every one got well, and Nimier reports from Tonkin that only 1 out of 23 cases proved fatal, and that not from the injury, but from an intercurrent dysentery.

Conservative treatment should be adopted unless amputation is necessitated by the great extent of damage done the bones and soft parts. By expectancy a very serviceable limb is generally secured. Care must be taken through the whole course of the treatment to keep the foot in proper position, as there is a strong tendency to its over-extension and to lateral deviation. If amputation must be done, it may be at the ankle or through the lower part of the leg, according to circumstances. Chauvel and Nimier have suggested that at times, when the destruction has been of the parts about the heel and the posterior part of the sole, an osteoplastic resection (the Wladimiroff-Mikulicz operation) might well take the place of an amputation.

Exsection of the ankle yielded very unsatisfactory results in both our own war and the Franco-German, and its death-rate was high (35.5

per cent. with us, nearly three times that of ankle-joint amputations, 13.43 per cent., and nearly 10 per cent. higher than that of leg amputations in general, 26.02 per cent.). It is doubtful if it ever will be much favored, as most if not all of its advantages can be secured by an informal removal of fragments if any active interference is required, and this will not often be the case. As with joint-wounds generally, by a strict antiseptic treatment and firm immobilization not only will life be saved, but a serviceable limb secured—far better, as a rule, than any artificial leg. Occasionally, of course, here as in other articulations there may be such persistent bone-disease as will compel a late operation—sequestrotomy, excision, or amputation; but just in proportion as an aseptic state of the wound is secured and maintained will the likelihood of this be diminished.

Wounds of Regions.

Head.—Injuries of the head are among the more common wounds met with in war, and of not infrequent occurrence in civil life. They are either of the scalp or of the cranium—many more of the former than of the latter as they come under treatment (7739 against 4350 in our late war). But it must be remembered that one-half of these head-lesions have proved fatal on the field, and it may reasonably be expected that a much larger number will be killed by the new bullet, because of its greatly increased velocity.

The scalp-wounds are either contusions (rarely met with), lacerations, perforations, or penetrations with lodgement of the ball. Injuries of the latter class have been but seldom seen in military service, and are not likely to be produced by the modern missile—never except when it is very near the end of its flight. Pistol balls, especially those of small calibre, are often buried in the tissues, frequently much flattened. Commonly they can be easily felt or their situation determined by probing. When in the temporal muscle their location may be indicated only by pain upon movement of the lower jaw and upon pressure above the zygoma. Laceration of a temporal or occipital artery may give rise to considerable hemorrhage and, as is the case in other traumatisms of the scalp, the development of a condition simulating depressed fracture. Such blood-accumulation, if not rapidly absorbed, should be aspirated or cut down upon and washed out with an antiseptic solution. Properly treated, these injuries may be expected to be readily recovered from, though heretofore the mortality-rate has been from 6 per cent. to nearly 30 per cent. in different wars, the fatality being consequent upon septic disease of one form or another. The ordinary antiseptic treatment should be thoroughly carried out, the bullet if lodged being removed when its location has been determined.

The cranial lesions are those of either contusion, penetration, or perforation. Contusions, which were about 7.5 per cent. of these lesions as met with during our war, are produced by the glancing impact of a rapidly-moving missile or the direct blow of a shot having but little momentum. They probably will not be caused by the new bullet, as almost certainly it will fracture the bone when it strikes it. As is the case with like injuries of other bones, the damage done may be slight,

giving rise to no symptoms; or more severe, causing limited extravasations, after a time absorbed, or superficial necrosis and exfoliation; or sufficiently great to cause a separation of the outer table over a small surface; or, but very rarely, to destroy the vitality of the entire thickness of the bone. The inner table may be fractured, with more or less displacement of fragments toward the interior of the skull, but this is of infrequent occurrence (Fig. 34).

FIG. 34.

Gunshot contusion of cranium, with fracture of internal table, exterior and interior view (A. M. M., Spec. 2313).

The wound becoming infected, inflammation of the diploic veins is very likely to follow, with resulting pyæmia with abscesses in the lung or liver, or a suppurative meningitis. Rarely is the "puffy tumor" of Pott present.

It is to such infection that the fatality of these contused injuries has been chiefly due, the percentage of which reached 16.8 in our war, and the prevention of such septic conditions will ensure recovery in the great majority of the cases—in all, we may expect, except those in which fragments of the inner table are driven down or the associated brain-concussion, laceration, and hemorrhage are of themselves mortal. The wound must be thoroughly cleansed, an antiseptic dressing applied, and the patient kept quiet. If constitutional symptoms of decided severity arise, indicating infective inflammation of bone or meninges, the contused area should be freely exposed and trephining done. The operation as now conducted will not add to the gravity of the case, whatever may have been true of it formerly, and it will make it possible to remove any detached pieces of the internal table, to disinfect, and to secure drainage. Sometimes—and, unfortunately, not so very rarely—no symptoms of moment are present for many days, when suddenly violent headache is experienced, followed by convulsions, coma, and death from cerebral abscess. For three months or more, the hundred-day period of Paré, the patient is exposed to this danger.

Except in the mildest cases, such as may readily escape detection, and frequently do so, there is usually, after recovery from the immediate effects of the wound, and it may be for a long time, more or less headache, often associated with dizziness, intolerance of light and sound, nausea, and vomiting. Epilepsy, paralysis, and mental irritability have in many cases been produced, as in similar contusions from violence other than gunshot. The prognosis, therefore, is more grave than the mortality-rate would indicate. Occasionally, though not often, bone-atrophy follows, exceedingly seldom hypertrophy.

The fractures produced by gunshot are graver lesions than those consequent upon other traumatisms, because of the greater intensity of the vulnerating force. Association of brain-injury is more constant and the visceral damage much more extensive; and this whatever the form of fracture, which varies from a linear break to a shattering of several, it may be all, of the bones of the skull. This shattering in bullet-injuries is due, as in other fractures of the head, to fissures starting from the original wounds, to vibrations conducted along the cranial thickenings from vault to base or from the occipital bone forward, and also, and much more largely, to the hydraulic pressure set in action by the ball as it passes through the brain. Numerous experiments, beginning with those of Busch and Kocher, have proved beyond question that there is such pressure in gunshot wounds of semi-fluid tissues, that it is proportionate to the fluidity, and that it is most strongly manifested in the brain, which is structurally fitted to develop it and is confined within rigid walls that will in the highest degree display the effects of it. Within the zone of explosive action, which with respect to the head extends, using the modern arm, to 600 or 800, even to 1000, yards, this hydrodynamic pressure produces wide destruction—so wide that life is very unlikely to be preserved. At close range brain and bone may be blown into fragments—less likely to be with the small- than the large-calibred bullet. Wagner of the Austrian army, having observed nine suicidal cases among soldiers in which death was immediate, reports that there was less destruction than in similar cases previously seen in which a large ball was used; the greater part of the brain was intact, there was less crushing of bone and less fissuring, and the greatest damage was about the wound of exit. Only exceptionally does the hydraulic pressure cause fracture of the base, and then in the great majority of the cases it is the ethmoid or the orbital surfaces of the frontal that are broken, though it is possible, doubtless, that the thin plate of the temporal covering the internal ear may yield. Pistol balls do not ordinarily have sufficient momentum to develop an explosive action, but wounds produced by them at short range at times show splintering of the orbital plates, even with depression toward the orbital cavity. Much interest in such injuries has been taken since the death of President Lincoln, and a number of cases quite similar to his have been put on record. At the autopsy of the President the bullet, which had entered through the occipital bone, was found to have passed forward in the brain and lodged just above the anterior portion of the left corpus striatum. Both orbital plates were comminuted, the fragments being forced inward; the dura mater, however, was uninjured.

The crushings caused by large shot and by shell-fragments, and the bullet wounds and those made by charges of small shot at close range

which are immediately or very quickly fatal, have no practical interest. It is in these cases, in which death occurs at once, that there is observed at times a stiffening of the body in the position had at the moment of injury. In a case in Northern New Hampshire some years since, in which the top of the head was blown off by a load of shot from a gun but a few feet away, the body of the woman was found sitting in a chair before the fire in the attitude of knitting, with the needles which she had been using still held in her hands. This "traumatic cataleptic rigidity," though met with in those shot through the chest and abdomen, is usually associated with cranial injuries.

As in other bones, there may be in the skull groovings, fissurings, penetrations, and perforations. The groovings are usually associated with fissures, which may affect only the external table, but are generally found to extend through the entire thickness of the bone—always, perhaps, except when it is "the supraorbital ridge, the zygoma, or the mastoid or occipital protuberance that has been struck, or the lesion is caused by a sharp fragment of shell" (Otis). In individuals who have passed the age of puberty the outer wall of the frontal sinus may be broken in without accompanying injury of the inner wall, rarely happening, however, except when it is a pistol ball that is the vulnerating body, the shot often lodging in the sinus, from which it may be readily extracted. In children penetration in this region almost certainly means piercing of the entire thickness of the skull and wound of the brain.

When both tables of a cranial bone are broken from without the damage to the internal is usually decidedly greater than that to the external table, the more so as the fracture of the latter is circumscribed. Such injury is in accordance with "Teevan's law," that fracture always commences in the line of extension, not that of compression. When the vulnerating force acts from within, the splintering is greatest in the outer table, which then might be named the "vitreous" one, cases of injury of this kind being observed in suicidal and other shots through the mouth and face, when the ball, ranging upward, emerges through the vertex. In the exit wound of a perforation there will be noticed the same excess of splintering in the outer table. The elasticity of the skull causes at times a return nearly to its original position of a fragment at first sufficiently depressed to permit of the entrance of a bullet. In a few cases penetration has been indicated only by the presence of hair in the fissure, as in those reported by Assistant Surgeon Howard of our army and by Koenig;[1] and it is possible, as in a case of v. Bergmann's, that a piece of a projectile may upon autopsy be found in the brain, and nothing but a mere crack be discovered through which it could have entered.

When the momentum of the ball is not great the fracture may be confined almost entirely to the surface struck, slight depression occurring or a piece of the skull of about the diameter of the missile being driven in below the general level of the internal table. Such a typical punctured fracture is not likely to be observed except when the ball is small, fired usually from a pistol or a toy rifle. In cases of more

[1] In a case reported by Matthew, from the Crimean War, hair was found in a fissure of the external table only.

extensive, but still not great, splintering the lesion is commonly confined to the bone struck or passes but little beyond it.

Penetrating and perforating wounds are always very grave injuries. The brain is seriously damaged in those wounds of this class not speedily causing death from shock and hemorrhage, and in cases of penetration there are the added dangers consequent upon the presence of bone-fragments and the missile. The shot may pass antero-posteriorly, laterally, or obliquely at any angle, rarely from below upward, and almost never directly from above downward, except when produced by bursting shells. Basal fractures, which are not very common, are met with as continuations of those of the vault, or in wounds through the neck or face, largely suicidal.

That a cranial fracture (other than of the internal table alone, which is always conjectural) has been received is usually readily determined by palpation, by inspection, by probing, or by percussion, which may give the "cracked-pot" sound. The course of a ball which has not passed through is often very uncertain, the missile frequently striking the opposite wall of the skull and being deflected, it may be at a large angle. To trace it a probe must be employed. If metallic (one made of aluminum is far the best), it should be used with light hand, the head being inclined and the instrument allowed to fall by its own weight, since it is very easy to push it through the soft cerebral mass. Oftentimes a moderately firm, elastic one, such as an urethral bougie, will be preferable. Always the instrument must be surgically clean, and it should be used only after careful disinfection of the external wound and the parts about. It is in these injuries that the telephonic probe has been found of service. If probing shows that the track has passed across the head, but the missile is not detected, a button of bone should be removed over the end of the canal, and search be made back along the track from that side or for the opening of the new canal made after deflection. As in the memorable case reported by Fluhrer in 1884, a second trephining may have to be done to find the course of the shot yet further deflected. Before any exploration of the track is made the opposite side of the head should be carefully examined, as it may be that the ball lies under the skin or is in the bone, and is forcing it out in such way as to be easily felt or to be indicated by pain on pressure. If the missile cannot be found after reasonable careful search—and very often this is the case—it will have to be left. Occasionally cerebral symptoms (paralysis or disturbances of smell, sight, or hearing) will indicate, if not the location of the ball, at least the course that it has taken; but these symptoms are less reliable than they otherwise would be because of the widespread injury of the brain outside of the immediate track of the shot. The symptoms of basal fracture are the same as those of similar injury from ordinary violence. The development of complicating septic inflammations is indicated by the usual symptoms of such affections. As is the case in the ordinary traumatisms of civil life, meningeal suppurations are accompanied with decided elevation of temperature; those of the brain are not, and no paralysis occurs in meningitis at the base. Fungus cerebri, misnamed hernia, has been met with (at least sixty-one times in our war), and must be so in the future in cases that have become infected.

The **prognosis** is always grave. As has been stated, one-half of those wounded in action never come under care, and of the other half

73.8 per cent. died in the Crimea, 46.1 in 1859, 59.2 in 1861–65, 51.3 in 1870–71. Of perforating and penetrating wounds in our war, 80 and 85 per cent. proved mortal. Balls lodged in the frontal lobes have been better tolerated than those elsewhere. Though much of the fatality heretofore has been because of septic complications, much of it has been from causes, chiefly shock and hemorrhage, that no treatment could have prevented. Of the 91 pistol-shot wounds occurring in recent years, tabulated by Bradford, 51 died (56 per cent.), and of these 39 (42.86 per cent.) died within a few days, 19 (21 per cent.) within a few hours; that is, 76.47 and 37.21 per cent. of all who died. As representing the probable death-rate under present methods of treatment and in a class of cases more likely to recover than those in which the damage has been done by an army bullet, the pistol-ball injuries studied by Bradford are very instructive. Of 25 cases shot in the temple, 16 (64 per cent.) died; of 5 in which the ball entered through the ear, all died; when the bullet entered in front of the plane of the external auditory meatus, 59 cases (57.7 per cent.) died; when in such plane or posterior to it, 32 cases (59.4 per cent.) died; the mortality when the ball was removed was 33⅓ per cent., when it was left, 54 per cent.; of 25 cases treated expectantly, 52 per cent. died. Lesions of the anterior part of the cerebrum were thought by Guthrie to be more grave than those of the posterior, and so Bradford found them in a percentage of 1.7. Wharton's table, however, shows a much heavier death-rate in wounds through the occipital bone, and in the Crimea the wounds in the anterior half of the head proved to be less dangerous. Wounds from side to side, especially those through the ear or very close to it, are much more serious than antero-posterior ones. In part this may be due to their being largely suicidal injuries, and therefore received at very close range, the mental condition, moreover, having of itself in these wounds, as in those of other regions, a depressing influence, decidedly increasing the risk to life. Lesions of the cerebellum almost always prove quickly fatal. Meningeal inflammation and brain-abscesses are excessively dangerous, as they always are, though by opening up the inflamed area, if it is a limited one, evacuating the pus, and securing proper drainage, relief at times may be afforded. Fungus cerebri is very apt to terminate fatally, especially when actively treated; 82 per cent. of the cases reported in 1861–65 died—a mortality-rate, however, much greater than in all probability will occur hereafter. But death in a few days or a few weeks is not the only bad result of these cranial fractures. Injury of the optic nerves causes blindness—of the auditory, deafness. Necrosis of bone, rarely caries, was formerly very common, and must always occur at times despite the most rigorous antisepsis. Cerebral disturbances of all kinds have been noticed again and again, and in greater or less measure are almost certain to come on. Epilepsy, paralyses, headaches, amnesias, changes in temper and in habits, imbecility, insanity, diabetes, each has often appeared, and that, not seldom, years after apparent recovery. When the ball remains in the head it ordinarily does not become encapsulated, but slowly moves under the influence of gravity, and because of the pressure exerted by it and the organic changes induced by its irritating action the almost absolute certainty is that some form of brain-trouble will at some time manifest itself.

The **treatment** of these lesions has reference to the wound itself and to the complications that may arise. As has been already stated, much of the fatality is consequent upon shock and primary hemorrhage, for the relief of the former of which, when severe, nothing can be done, and but little for the latter, the cases occurring in military practice and living long enough to come under care being almost certainly hopeless. In the wounds of civil life, if the bleeding is from an external vessel, compression may arrest it, but, as a rule, ligation should be done; and such should be the practice when a meningeal artery (usually the middle) has been injured. It may doubtless at times be found advantageous to introduce a sterilized gauze plug when the hemorrhage is from the track of the bullet in the brain; and in certain exceptional cases perhaps, when the compression-symptoms indicate a progressive bleeding, ligation of the carotid may be of service.

The wound being from pistol shot, the scalp should be shaved, the damaged area antiseptically cleaned, and if penetration has occurred a button of bone including the entrance wound removed by trephining; in other words, the injury should be treated as though it was an ordinary punctured fracture of the skull. Removal of the bone does not add to the gravity of the lesion, and permits of the taking away of any fragments that may be present at the orifice and the more ready examination of the track within. Careful search for the ball and deeply located bone-splinters should then be made, and if found they should be removed with a forceps no larger than is absolutely required. But in searching and extracting care must be taken to do as little violence as possible to the brain already seriously injured. When the foreign bodies have been taken out, or if the bullet is not found, or if found is at such depth as to make it unwise to attempt its removal, the blood-clots and devitalized tissue in the canal (which is always of a diameter much larger than that of the missile) should be washed out very carefully or scraped away, a drainage-tube introduced, and an antiseptic head dressing applied. If the ball has passed through and out, the exit wound also may be trephined, or only its detached fragments removed to such extent as will allow of free drainage. Here the external table is certainly as much, probably more, splintered than the internal, and the ends of partially separated sequestra are pushed away from the meninges and brain instead of toward them. The securing of thorough drainage is of the highest importance, for increase of pressure upon the brain from extravasated blood adds much to the gravity of the wound. If, though the ball has not passed out, it can be located under the skin or in the bone, it should be removed and the injury thus converted into a perforating one.

Bradford's statistics indicate that cases in which the lodged ball is removed after trephining are more likely to recover than those of perforation, probably because in the great majority of such cases the bullet has not penetrated deeply and the brain has been less seriously damaged. These statistics further show that if the bullet remains in the head the termination of the case is about the same whether any operative interference is made or the case is treated expectantly.

When the wound is produced by one of the new rifle bullets, if the missile enters the cranial cavity it will, except at an extreme range, pass through, and there will be no occasion for searching for it or extracting it.

If the lesion is not one of penetration, the fracture should be treated on the same general principles as apply to a similar one due to an ordinary trauma, trephining being done or fragments being removed in a more informal way whenever there is depression or any decided comminution. The adoption of aseptic and antiseptic methods of operating and dressing has greatly changed the status of these procedures, which as now carried out do not, or but in slight degree, expose to the danger of the lighting up of septic inflammation, the development of which in former times was so general and so fatal. Any discovered clot under the skull or under the dura should be removed by irrigation or by the finger or an instrument.

The secondary complications that may arise and that demand treatment are the infective diseases of the meninges and brain, with resulting diffused or circumscribed collections of pus, and secondary hemorrhage. Meningitis and meningo-encephalitis, which ordinarily come on from the third to the sixth day, but are often deferred for as many weeks, and which present no features other than those met with in cases of traumatisms not produced by gunshot, are to be treated in the same way as in the latter, no treatment commonly being of much avail. They are to be prevented, if possible, by the adoption of a rigidly antiseptic wound-treatment, and without doubt it will be possible to prevent them in a considerable proportion of the cases in civil life.

When the symptoms present indicate the formation of cerebral abscess—and these, unfortunately, do not ordinarily show themselves until rupture has taken place into a lateral ventricle or the pressure exerted upon the brain is great—there should be an active interference at once. Trephining, if necessary, should be done, and exploration made by the use of an aseptic director, or, better, an aspirator needle, or such exploration be made through the already exposed meninges or cortical substance. There should be no hesitancy in carrying the needle deeply, and, if required, in various directions, in the hope of finding the abscess, since the exploration does not materially, if at all, increase the gravity of the situation, and only in prompt evacuation of the pus with the securing of after free drainage is there any chance of saving life. Occasionally such fortunate result will follow, but ordinarily the case soon terminates fatally.

Secondary hemorrhage, almost invariably due to septic changes in and about the wound, should be treated by ligation of the bleeding vessel, or, if this cannot be effected, of the main trunk, the external or common carotid. The mortality attending the latter operation, formerly great (68.75 per cent. of the cases reported during the wars of 1861–65 and 1870–71, 11 out of 16 patients dying), should hereafter be less in proportion as the fatal result was directly due to the ligation, though exhaustion from previous loss of blood, cerebral softening, or accompanying septicæmia or pyæmia must still carry off many of those operated upon. Ligation of the external carotid when the bleeding is from one of its branches should be preferred to that of the common trunk, as all recent experience has shown that it is a much safer operation (as 11 to 78), and at the same time more effective in controlling the hemorrhage. Fungus cerebri, if it forms, should be treated expectantly by moderate compression. Operations on such mass (ligation, excision, injection,

cauterization) have not usually proved of service, the mortality attending them in 1861–65 being 75.8 per cent.

In the treatment of basal fractures in which there is discharge of blood or serum from the nose, mouth, or ear, the nasal cavity, the naso-pharynx, and the external auditory canal are to be thoroughly disinfected and plugged with sterilized or antiseptic gauze.

FACE.—Wounds of the face are perhaps about 4 per cent. of those received in action (3.83 per cent. in our war), and are not seldom met with in civil life, where they are caused by small shot single or in mass, by pistol balls, and, in a very few cases, by pieces of caps or fragments of a gun that has burst. They are of interest chiefly because of the occasional occurrence of dangerous hemorrhage, primary or secondary, or of the not infrequent extensive lacerations that they produce and the resulting deformity, often very disfiguring. Their mortality-rate has not been great—4 to 7 per cent. in different wars, and this chiefly in the cases of fracture, flesh wounds rarely causing death (in 1.5 per cent. only of the nearly five thousand (4914) cases tabulated by Otis). Even this rate may be expected to be much lowered hereafter in degree proportionate to protection against sepsis. Flesh wounds made by pistol balls fired from a distance or by small shot are attended with but little destruction of tissue, and are quickly recovered from, the resulting scarring being usually but slight. Occasionally the bullet or charge of small shot seriously damages the eyelids, the lips, or the soft parts of the chin, with later cicatricial contraction that may necessitate operative treatment. Generally, however, these graver lesions are associated with injuries of bone, which occur in about one-third of the cases. Any bone may be injured, but most commonly it is the inferior maxilla, the fracture of which much resembles, as respects splintering, that of a long bone. The superior maxilla was frequently much comminuted by the old large-calibred bullet, though the fragments were generally adherent; with the new bullet in the middle ranges much less splintering may be expected to be produced. Pistol balls crush it but little, as a rule, except when the weapon is discharged at very short distance, and not always then. The cavities, orbital, nasal, and oral, are often penetrated or perforated, the shot at times doing no direct damage to the eye or tongue. Their penetration may take place without any injury to bone. A bullet may pass out through the mouth or the anterior nares, not wounding, or but slightly wounding, the lips or the nose. In a case reported from the Franco-German War a ball entered through the anterior nares, struck the posterior pharyngeal wall, and, rebounding, made exit through the mouth. When the missile passes antero-posteriorly the brain, spine, or great vessels of the neck are often damaged, though not seldom in suicidal wounds through the mouth the brain is uninjured, backward jerking of the head causing the ball to take an upward course in front of the cranial cavity. When the bullet enters the brain through the orbit or the mouth, death is almost sure to follow from the primary injury or secondary septic inflammation. Passing transversely, one or more of the larger blood-vessels of the face or upper part of the neck may be wounded, and it is the likelihood of the occurrence of such lesion that renders injuries of the body of the lower jaw of grave import. Lodgement of the ball, especially in pistol shots, often occurs, such lodgement being in bone or in one of

the cavities—the frontal sinus, the antrum, the nasal fossa, or the orbital cavity. In many cases, after having remained in the face for a long time the bullet has been spontaneously extruded, or, having ulcerated its way into the nasal fossa, has been removed. In effecting such removal through the anterior nares (it should not be pushed backward, lest it drop down the throat) much difficulty is often experienced, particularly so if the bullet is deformed. In such case the nasal outlet should be enlarged, or, better, the fossa opened through the vestibule of the mouth by turning up the lip after the method of Rouge—an operation which gives free and ready access to the nasal fossa and leaves no after deformity.

Striking an orbital ridge, the soft lead ball has frequently split. The eyeball is quite often wounded, in civil life many of the injuries being caused by pieces of cap or small shot. As a result the eye, if not destroyed at once, is very apt to be lost through inflammation, and there is always much danger that sympathetic ophthalmia will be developed in the other eye if the injured organ is not promptly removed. In a transverse wound of the face the bullet may cut off the optic nerve, producing immediate blindness, or so contuse it or lacerate the parts immediately about as to cause, through nerve-concussion or inflammation, or through pressure from a clot, temporary or permanent loss of vision. A like loss of vision may be consequent upon a wound in the forehead, by some attributed to a reflex disturbance from a damaged supraorbital nerve, but generally due to fracture running through the orbital canal (that Berlin found to exist in every one of the thirty-four cases that he examined), though it may be because of retinal hemorrhage from concussion.

Wounds of the side of the face may involve Steno's duct and cause a salivary fistula. Generally such a fistula may be expected to close spontaneously, and only very exceptionally will it fail to do so under ordinary treatment.

Passing through the mouth, a bullet often wounds the tongue, either grooving it or tunnelling it. The resulting swelling of the organ, which rapidly comes on, may reach a high degree, so as much to interfere with speech, swallowing, and breathing, and to cause protrusion beyond the line of the teeth. The lesions, however, are not grave, except when the wounds involve its under part and the lingual artery or one of its large branches is torn. Not infrequently a tooth or a piece of a tooth is driven into the tongue, where it may at times be felt, often being mistaken for a lodged ball until its removal. In rare instances the ball does lodge, and cases are on record in which it has remained in place for years.

The **treatment** of these face-wounds is by expectancy, except as vessel-lesions necessitate ligations. Entirely detached fragments of bone are to be taken away; but only such, any adhesion, bony or periosteal, being sufficient ordinarily to preserve vitality. By manipulation partially adherent sequestra can be largely brought into place, and if in the lower jaw they cannot be properly maintained in apposition, they may be wired together. As is true in all the face-wounds ordinarily coming under care, none of the soft parts are to be cut away, no matter how extensively torn and crushed. When in communication with the mouth or nasal cavity the wounds are always more or less septic, and great care must be taken to keep them as clean as possible, frequent irrigations being required. Besides the ordinary reasons for maintaining

cleanliness, there is here the additional one that grave disturbances of nutrition will be induced by the passage into the stomach of foul discharges from the mouth.

Primary hemorrhage, when not from one of the large trunks, either ceases spontaneously or is arrested by the application of hot water or by compression. When from the tongue, it may be so profuse as to necessitate plugging of the wound with gauze, its closure by sutures, the use of the hot iron, or the ligation of the lingual or external carotid artery. If it is one of the main arteries that has been torn, the bleeding point should be found if possible, and a ligature applied above and below; and if this is impracticable, ligation should be done of the trunk near its origin, of the external carotid, or (but never when it can be avoided) of the common carotid.

Secondary hemorrhage, if severe, always if recurrent, should be treated by ligation, which frequently, because of the condition of the parts, will have to be at a distance. As has been stated before, chemical styptics should never be employed: many a wounded man has lost his life through violation of this rule.

Following destruction of tissue, soft and hard, cicatricial contractions are often met with, affecting the eyelids, the nose, the tongue, or the temporo-maxillary articulation, producing deformity and impairing, in high degree, it may be, the functional action of the parts. For the relief of these, plastic operations may have to be done upon the eyelids or the nose; the tongue loosened up; and a jaw-ankylosis treated by excision of the band or by resection of the joint, or, better, the establishment of a new joint in front of the angle, according as the ankylosis is false or true. Much can often be done by plastic operations or by the application of a proper prothetic apparatus when there has been an extensive loss of substance, the result generally of wound by a cannon shot or shell-fragment. It has long been known that recovery takes place far more frequently than would naturally be expected in these often frightful destructions of the face. When the superior or inferior maxilla has been crushed and much of the bone has been lost, in the process of healing considerable approximation of the remaining fragments may take place, much lessening the amount of plastic or mechanical work that will have to be done to repair the damage or to conceal the deformity.

NECK.—About one in fifty of those wounded in action and reporting for treatment has been found to be shot in the neck. For practical as well as topographical reasons the wounds may be classified as of the antero-lateral and of the posterior regions, the line of separation conveniently following the anterior borders of the trapezius muscles. In front of these borders, except when very superficial, gravity attaches to the wounds because of the danger of a complicating injury of important vessels or nerves, of the air- or food-tubes, or of the spine—injuries, however, that are of comparatively infrequent occurrence, though often enough met with to make the mortality-rate of the lesions, taken together, from 4 to 33 per cent. in different wars, 15 per cent. in our war.[1] Such infrequency would be very surprising, considering the number and size

[1] The number of wounds of the larger vessels in 1861–65 was 235 (211 arteries, 24 veins), about 1 in 21 of the injuries of the region; of those of the air-passages, 75, about 1 in 50; and of the pharynx and œsophagus, 29, about 1 in 170.

of the vessels, the exposed position of the larynx and trachea, and in less degree of the pharynx and œsophagus, and the size of the vertebral bodies and the spread of the posterior arches, were it not for the knowledge that the great majority of those wounded in these parts are left upon the field, having been over 3 per cent. of those killed among the German troops in 1870–71. The posterior wounds chiefly damage the muscles, though occasionally the spine is injured, and their mortality-rate is very much lower than that of those located farther forward. These muscle-wounds, whatever the region, are of interest only on account of the tendency to subsequent contraction and the formation of adhesions, which, one or both, may decidedly limit the motions of the head. Any produced torticollis is likely to improve as time passes, but not seldom the deformity has been a persistent one.

In the anterior and antero-lateral wounds, if suppurative inflammations arise, there is a strong probability that unless speedily prevented by free incision and thorough drainage it will extend along the fascial planes into the chest or the axilla. Such inflammations, formerly so common and often so grave, may now be expected to be prevented in the greater part of the cases treated.

Hemorrhage as met with in military practice will ordinarily be secondary, occasionally intermediary, almost never primary; in civil practice, the cases, as a rule, coming under care comparatively quickly, early bleeding will be more often seen. It is to be treated as in other regions; when from an artery, by ligation if that can be effected, otherwise by compression; when from a vein other than the internal jugular, preferably by compression, which often answers the desired purpose. The internal jugular had better be tied, though its wounds have been so uniformly fatal that there is not much to encourage operative interference. The difficulty not seldom experienced in determining what vessels have been wounded or of getting at the bleeding point in the midst of the infiltrated—it may be sloughing—tissues will often compel ligation at a distance. As has already been stated, the external carotid should be tied for a wound of one of its branches rather than the common trunk, and when there is uncertainty as to whether it is the external or the internal carotid that has been damaged, the vessels should be exposed at the bifurcation, pressure employed on them alternately, and that one tied the compression of which arrests the bleeding. Past experience proved the dangerous character of these ligations in the neck; in the future there ought to be a lessened death-rate in proportion as septic infections are prevented. Of the 76.8 per cent. mortality after ligation of the common carotid in our war, and 68.75 per cent. among the Germans in 1870–71, a decided proportion must have been due to infection, more than would appear from the published statistics; and the same is true of ligation of the subclavian and its branches (74.5 per cent. in 1861–65).

Aneurism has occasionally developed after these injuries—eleven times in 1861–65, with 9 deaths (81.8 per cent.), ligation saving 1 case out of 5 (common carotid), and without ligation 1 out of 8 surviving, also of the common carotid. In a very few cases an arterio-venous aneurism has formed, wounds of the vessels having established a communication between the internal jugular vein and the common, the internal, or even the external carotid artery. Such aneurism has proved

but little dangerous to life, though cerebral softening has been known to follow, the more serious effects ordinarily met with being headaches, dizziness, and the annoyance of the persistent bruit and thrill. As respects treatment, non-interference should be the rule of conduct.

Nerve-lesions, as might naturally be expected, are frequent (in 1 in 12 of the neck-wounds among the Germans in 1870–71), many due to direct injuries of the trunks, some to associated wounds of the spine, even contusion of which may be followed by temporary paralysis, affecting in rare instances the four extremities. Wounds of the larger nerve-cords produce impairment of motion and sensation in the parts supplied, of varying degree according to their extent, and reflex disturbances may be set up in regions quite remote. Lesion of the hypoglossal nerve has caused motor paralysis and unilateral atrophy of the tongue; that of the sympathetic, contracted pupil, ptosis, and flushing of one side of the face; to injury of the pneumogastric Larrey attributed the intense thirst which is at times experienced after wounds of the œsophagus. The brachial plexus being wounded by ball or bone-fragment, not only may there be paralyses of the muscles of the extremity, with after contractures, but trophic changes in the skin, and that burning pain (causalgia) which is, as Mitchell has declared, "the most terrible of all the tortures which a nerve-wound may inflict." Serious nerve-symptoms have at times been consequent upon the pressure of a lodged ball, ceasing when the bullet has been removed. Several important nerves may be injured by the same shot, as in a case reported by Stromeyer in which the phrenic, the pneumogastric, the middle ganglion of the sympathetic, and the descendens noni were wounded, together with the larynx and pharynx.

The superficial position of the larynx and trachea exposes them to considerable risk of being wounded, either alone or together or in association with injury of the pharynx or œsophagus: 82 such cases were reported during our war, and 59 among the Germans in the Franco-German War. Their mortality is heavy (42.7 per cent. in 1861–65, 55.9 in 1870–71), more so in tracheal than in laryngeal wounds; but much of such fatality may fairly be attributed to accompanying lesions of blood-vessels, spine, etc. In civil practice these injuries are commonly much less serious, especially when made by small shot, and are often contusions or groovings, not penetrations. The symptoms are, in general, difficulty of breathing, impairment of voice, spasmodic cough, and more or less bloody expectoration and pain, either or all of which may be present when the air-passage has only been contused. When penetration has occurred there may be in addition emphysema, a passage of air through the wound on expiration causing a more or less decided blowing sound, and, if the pharynx or œsophagus has also been opened, an escape of liquids, though this latter symptom is not certain proof of lesion of the food-tube, since it may occur because of an inactive epiglottis. If a laryngoscopic examination can be made, the internal wound or the lodged shot may at times be seen. Œdema of the larynx may come on rapidly and at any time, or the trachea be later compressed by blood or exudations outside of it. Hemorrhage into the air-tube may cause its obstruction. So far as the wound itself is concerned, the treatment is that of wounds in general. The liability to the sudden and unexpected occurrence of suffocation makes it wise early to perform

tracheotomy, or at least to have the patient so carefully and intelligently watched that the operation may be promptly done if it should become necessary. Very possibly an early intubation might often be done instead of a tracheotomy, which latter operation in the wars of 1861–65 and 1870–71 was followed by death in 22 out of 34 cases (64.7 per cent.). A lodged missile should, if possible, be removed, as its presence is almost certain to cause trouble sooner or later. It has been known to ulcerate its way into the œsophagus and be discharged at stool. At times it may be taken out through the mouth by an intra-laryngeal operation. If the wound does not prove mortal, there is apt to be a permanent impairment of the voice; often because of existing cicatricial stenosis a tube has had to be worn; necrosis of the cartilages is not infrequent; and aërial fistulæ at times remain.

The pharynx and œsophagus are wounded much less often than the air-passages, but the mortality of such wounds is great (54.84 per cent. in our war), chiefly because of other grave lesions almost necessarily associated with them, though difficulty of feeding and the occurrence of food-pneumonia has not a little to do with it. Unless there is discharge of food through the external wound, the *diagnosis* will largely rest upon the determination of the direction of the shot, and often must remain only conjectural. More or less associated laryngeal disturbance may be expected to be present. As far as it can be done, escape of the food must be prevented by suturing, by packing the wound with gauze, or by the use of the œsophageal tube, according to circumstances, since the presence of food in the neighboring tissues is certain to cause an infective inflammation. In any case, suppuration occurring, free exit must be given the pus as soon as possible and drainage maintained. Much care must be taken to secure to the patient a sufficient quantity of food, given by preference, as a rule, through a tube. Strictures and permanent fistulæ have resulted in a small proportion of the cases that have survived the original wound.

A wound of the thyroid gland, if not complicated by tracheal or œsophageal injury, is of interest only because of the bleeding that occurs —bleeding to be controlled by ligation of the vessel or by suturing, plugging, or cauterizing the wound.

Spine.—In these wounds a vertebra may be contused; one or other of its component parts, body or posterior arch, fractured; or the canal opened, with associated lesion of the meninges or the cord, the latter being much the more severe injury. These wounds are produced by missiles (bullets or shell-fragments) striking the back, passing from side to side, and injuring the spine in its course, or coming from in front, affecting the vertebra only after having wounded the parts anterior in the neck, chest, or abdomen. It is to these last-mentioned complications that much of the great gravity of these wounds is to be attributed. As is true of head-injuries, this gravity is in but slight measure due to any existing bone-lesion, being chiefly due to the damage done the cord or its coverings, to concussion or compression from blood-clot or pus-collection, to organic changes in the meninges or the nerve-tissue, or to destruction of such tissue. Shock is always great, even to the extent of producing instantaneous death with following traumatic cataleptic rigidity; and the same physical conditions that favor explosive action

in the head are here present—abundance of fluid and a rigid bony envelope.

The **symptoms** are those of any and every injury of the cord, though more marked, as a rule, than after other traumatisms. They are impairment of the motions of the back; partial or complete paralyses of muscles of the trunk or extremities; anæsthesias and hyperæsthesias; peculiar and severe pains of a girdling, gnawing, tearing, or burning character; disturbances of respiration, of circulation, of defecation, of micturition; neurotic gangrenes, often of rapid development, in parts pressed upon, as on the back, over the trochanters or heel, or at the distal extremities of the limbs from defective blood-supply, such as not seldom also follow injuries of the nerve-trunks. Sometimes, when there has been penetration of the canal, this fact will be evidenced by escape of cerebro-spinal fluid; but this symptom is by no means a constant one, and when present only shows that the theca has been opened, not that the medulla has certainly been damaged. Contusions of the spine usually cause but temporary disturbance of motion or sensation, occasionally a meningo-myelitis; such inflammation, however, is lighted up less often than after similar injuries of the cranial bones. These effects, aside from those of infective character, are, as a rule, quickly recovered from without serious after-consequences, though at times stiffness of the back or some paralysis of an extremity remains, and in rare instances necrosis takes place, as in a case reported by Keen, in which there was spontaneously discharged, after about three months, "nearly the entire body of the third cervical vertebra, including the anterior half of the transverse process and the vertebral foramen."

The fractures that come under care are largely those of the spinous and transverse processes. Those of the body are much graver lesions, and that whether the bone-lesion be one of grooving, of penetration with lodgement of the ball, or of perforation. In them the bone is often much fissured. The lower in the column the fracture, the less severe it is likely to be, the mortality-rate, as stated in the *Medical and Surgical History* of our war, being 70 per cent. in the cervical, 63.5 in the dorsal, and 45.5 in the lumbar regions.

Hemorrhages outside of the dura, within the theca, or in the substance of the medulla, especially the first two, are very generally associated with spinal injuries, causing severe pain, often shooting around the body and serving to indicate the location of the injury. Such pain, when the extravasation is but slight, ordinarily subsides in a short time, returning again temporarily when the period of reaction sets in, and then, as absorption takes place, more or less rapidly passing away, together with the paralytic condition produced by the clot. When the clot is a large one, its pressure-effects are correspondingly great, and there is generally an associated infective myelitis. Compression of the cord is produced also by a lodged ball, or, more often, by depressed bone-fragments. As in brain lesions, there is here always more or less concussion of the medulla, and with the jarring there is usually associated contusion of greater or less amount, though the cord is more protected by the "water-bed" in which it rests than is the brain. Such contusion with its associated laceration varies from that which is quickly recovered from, without any organic change being produced, to that which is destruc-

tive to a part of the cord. The extensive tearings and crushings, however, are chiefly due to the action of either ball, bone-fragment, or both.

The **prognosis** in military practice has always been very grave, one-half, two-thirds, three-quarters, nine-tenths of the cases coming under treatment dying, the most of them within a few days. In civil life there is more chance of recovery, the injury, as a rule, being less severe and the patients coming sooner under care, and that after comparatively little moving. When the canal has been opened—by penetration or by perforation, it matters little which—the danger is very much greater than in other cases because of the compression or laceration of the medulla; the wound in those who have recovered heretofore having been almost always of the sacral or lower lumbar vertebræ; that is, below the end of the cord proper. Antiseptic treatment may be expected to lessen somewhat this mortality-rate, but in all probability its beneficial effect will not be very great, as in many cases it will be impossible to secure asepticity; and sepsis is by no means the chief cause of death, which so often must result from shock, hemorrhage, or associated lesions of important viscera. When there has been no injury of the cord or theca, other than perhaps a limited extravasation of blood outside the sheath or a slight concussion of the medulla, recovery may take place, and that with little after-disturbance, organic or functional, this being especially true of wounds of the processes, particularly the spinous. Rarely, however, is the wounded man so fortunate. Almost certainly there will later be stiffness and weakness of the back, impairment of function in arm or leg, muscular atrophies frequently with contractures, urinary troubles of greater or less severity, neuralgias, ataxias, mental disturbances, one or more; in other words, the primary lesion, if it does not kill, may be expected to be followed by chronic inflammations and scleroses that cannot but be greatly disabling, the effects of which may not perhaps be manifested for years. When a nerve has been damaged close to its intervertebral foramen, the parts to which it is supplied will be found to be seriously affected as respects both sensation and motion.

Treatment, aside from that to protect against infection and that of the ordinary complications of spinal injuries in general, has reference to the removal of foreign bodies and the securing of rest to the injured part. When the bullet has been located and its extraction is feasible, it should be taken away and the wound cleared of such non-adherent bone-fragments as can be found. Sometimes the extraction of the ball has been followed by hemorrhage sufficient to necessitate plugging. Rarely has ligation of an artery been required. Recently much attention has been directed to the performance of laminectomy for the relief of pressure, whether caused by a displaced fragment, by a blood-clot, or, later, by an overgrowth of bone. In the present state of surgical practice a properly-conducted operation of this sort does not materially add to the dangers of the case, and permits of a determination of the condition of the theca and cord, the removal of whatever may be pressing upon the medulla, the extraction sometimes of a ball lodged in the body of the vertebra, and the thorough cleansing of the wound. To open up the canal a trephine may be employed, or, better, the chisel and the cutting forceps. In gunshot even more than in other fractures of the spine, operative interference promises to be of very much service, freed as the operation now is of the

greater part of the danger of lighting up a septic meningo-myelitis. If it does no good, it will ordinarily do no harm. The cases in which it has been done are as yet too few to permit of their statistics being regarded as establishing a rule of conduct; but mere numbers of reported deaths and recoveries ought never to be so regarded. Sound reasoning and observation of the analogous ordinary accidents of civil life certainly now justify —more, authorize—the operation in any case in which there is not such associated injury of vessel or organ as makes recovery under any circumstances unlikely. The coexistence of any serious visceral lesion contra-indicates any operative interference. Whether an operation is done or not, the spine should be immobilized and rest as absolute as possible secured to the patient.

CHEST.—A considerable proportion of the wounded in action (6, 8, even 10 per cent. of those receiving treatment during a given war, and one-third to one-half of those killed outright) have been found to have been shot in the chest. In civil life such injury has been frequent, produced either accidentally or with intention. The wound may be of the parietes or involve the cavity by penetration or perforation, and if of the chest-wall may be associated with fracture (costal, sternal, vertebral, clavicular, or scapular) or with lesion of an important vessel or nerve.

When there is no such complication a non-penetrating wound is usually one of little moment—simply a flesh wound, to be treated in the ordinary way. Formerly, especially when the round ball was used, the missile at times ran for a greater or less distance around the chest, but such course will not be taken by the bullet of to-day, pistol or rifle; the exceptions to this rule being only apparent, involuntary muscular action, as shown by Bardeleben, so changing the position of the parts as to cause the actual straight line to seem to be a curved one.

As the result of the blow upon the chest, concussion of the lung in greater or less measure occurs, indicated by difficulty of breathing, pain, and the symptoms of shock, all usually of but temporary duration. When the force of impact has been very great, commonly in shell-fragment injury, contusions of the lung-surface, lacerations, or injuries of the main blood-vessels have occasionally been observed, the parts being forcibly compressed between the chest-wall (the elasticity of which permits of its being strongly crowded backward) and the distended lung, the air in which may be held in place by an associated closure of the glottis. In such injuries the concussion symptoms just mentioned are more severe, those of collapse are not seldom added, and a quickly fatal termination has at times been reached—an almost certain result when the laceration has been extensive. The occurrence of bone-lesion decidedly increases the gravity of the case, though in less degree now than prior to the adoption of the antiseptic method of treatment; and danger from this cause may be expected to be less in future wars than in those of the past in proportion as the new bullet is smaller than the old and produces less separation of fragments. The sternum may be grooved, and with the groove made by the modern missile there will probably be fissures, and very likely a transverse crack through the entire thickness of the bone; the rib-fracture will almost certainly cause injury to the pleura; the clavicle may, though very rarely, be transversely broken without splintering—ordinarily its fracture will be compound and comminuted;

the scapula may be perforated or extensively splintered; the vertebral injury will commonly be of the spinous process without injury to the cord or its coverings. The gravest of the non-penetrating wounds are those in which the axillary vessels, those just above the clavicle, or those around the scapula have been wounded, a decided proportion of which are quickly fatal. Rarely met with, these vessel-injuries may be more conveniently considered in connection with perforating lesions, of which they are at times complications. Taken all together, the external chest-wounds have a very low mortality-rate (1.5 per cent. in our war—1 per cent. only excluding the fracture cases). Their treatment is the ordinary antiseptic one, combined with comfortably firm bandaging of the chest or immobilization, as far as may be practicable, of the whole thoracic region. When pneumonia or pleuro-pneumonia comes on in consequence of lung contusion or laceration, it is to be treated in the usual way, though in the absence of the specific infective organisms of true pneumonia or those of suppuration the traumatic inflammations are of mild character.

Of far greater severity, though fortunately of decidedly less frequency as they come under care, are the penetrating and perforating lesions. Among wounds received in action hereafter rarely will there be found one of the former, the new bullet almost certainly passing through and out, and in the large majority of pistol-shot wounds the ball is now found to perforate either completely or so far as the thoracic cavity is concerned. The result is and will be that a larger percentage of the cases not quickly fatal do and will get well, freed as they must be more or less completely from the dangers of suppurations, fistulæ, and septic infection. Prompt healing characterized the cases observed by Stitt in the late Chilian War. Even when the ball has lodged, if let alone it commonly does no harm when an aseptic or antiseptic state of the wound is secured. Never again, probably, will the death-rate of the cases treated reach 80 or 90 per cent., as in the Crimea, or 65 per cent., as with us, or 68 per cent., as in 1870–71. Very much more than half of the pistol-shot cases in our hospitals recover; indeed, death is exceptional in those not almost necessarily fatal from the nature of the injury.

Wounds of both lungs, the shot having passed from side to side or very obliquely antero-posteriorly, are and must be grave lesions, because of shock, hemorrhage, or developed septic inflammations, but because of the smaller smoother bullet and protection from sepsis they are now, and will be in the future, less frequently than heretofore followed by death.

Multiple wounds are but little if any more dangerous because of their number, their gravity being determined by the character of the individual injuries.

That penetration has occurred may or may not be clearly apparent, the only positive proof of lung-wound being afforded by protrusion of a part of the organ (primary hernia), the regular to-and-fro passage of air synchronously with the respiratory movements (traumatopnœa), actual inspection of the lung through the wound, or upon digital exploration. The evidence from neither sight nor touch is obtainable in the ordinary bullet wounds of to-day, and the hernia and peculiar breathing only very

rarely are to be observed. Probing should not be resorted to, as if the diagnosis cannot be otherwise made it is not necessary to establish it, and much harm may easily be done by such exploration. When there is present a wound of exit as well as one of entrance, and the line joining them passes through the cavity, it may now be taken for granted that there has been penetration, for deflection of such bullets as are in use (other than perhaps the smallest) will not occur. Emphysema also might be regarded as proof positive were it not for the fact that in a limited degree it may be present in a non-penetrating injury, air sucked in from without being, because of the valvular character of the track, prevented from entirely escaping upon expiration.

The rational symptoms, in general, are pain, difficult, or more properly constrained, breathing, spitting of blood, and cough; there being in addition, when air or blood in quantity is in the pleural sac, compression of the lung on one side with diminution or arrestation of the chest movements on that side, increased resonance on percussion when air, diminished when blood, is present, with shock or collapse symptoms in greater or less degree. Penetration may occur without injury to any part other than the pleura, the ball cutting it in passing across the chest between two ribs—an accident probably of very infrequent occurrence, very unlikely to be recognized, and without interest except such as attaches to the non-penetrating wounds.

Complicating these wounds are hemorrhages, lodgement of foreign bodies, fractures, accumulations of air or pus in the pleura or of pus in the mediastinum, and associated lesions of the spine or of the parts below the diaphragm. The bleedings may be either external or into the chest-cavity, the former when other than slight being ordinarily from the large arteries or veins in the neck or axilla, the latter from the intercostals, or, much less frequently, the internal mammary artery, from the great vessels in the chest, or from the heart, those from the last two sources commonly causing death so promptly that they need not now be considered. Bleeding from the lung-tissue is ordinarily not very abundant, especially when the wound is toward the periphery of the organ, though to it is to be attributed the bloody expectoration which is so frequently observed during the first few days, and in some cases the produced hæmothorax—a complication, so far as it comes under treatment, commonly due, however, to injury of the intercostals. The hemorrhages from the axillary or subclavian may be either primary or secondary, in the former case the blood being discharged externally or infiltrating the surrounding tissues, forming a false aneurism. In a few cases late opening of the subclavian has been consequent upon the fretting away of the arterial wall by the rough end of a clavicle-fragment.

The lodged foreign bodies have usually been bullets, which have become encysted, remaining at times for years without doing any harm, or have been coughed up or by ulceration worked their way into the œsophagus to be later discharged at stool (occurrences that have been very infrequent), or have dropped into the pleural cavity to remain or to be removed after opening of an empyema. No such lodgement may now be looked for except in a small minority of the pistol-shot wounds, and in these cases encapsulation may be expected very generally to follow.

Fractures are of much less importance as complications than hereto-

fore, except when fragments of the broken bone (commonly a rib) are detached and driven into the lung, and even then the resulting danger is decidedly less than formerly. Protected from the development of septic inflammations, neither a costal nor a scapular fracture produced by an outgoing ball adds materially to the gravity of the case. Heretofore fracture of both scapulæ has been largely a fatal injury, but will be so hereafter only as the result of associated lesion of the spine or of important structures in front of it.

Pneumothorax is but little likely to follow wounds made by the modern small-calibred ball, and is very rarely seen to any serious extent after pistol-shot injuries.

Pus-collections in the lung, the mediastinum, or the pleural sac must also be much less frequent than before, though no antiseptic treatment can be pursued that will prevent such infection of the blood-clot in the pleural cavity as is produced by organisms coming in through the air-passages, or overcome the septic influences of discharges into the mediastinum from an opened œsophagus—a complication of extreme rarity, yet which may be present.

Associated wound of the abdomen, as might be expected, is one of the graver complications, about three-quarters of the cases terminating fatally, but fortunately is not very common, having been observed in less than 1.5 per cent. of the chest-wounds reported by Otis. In civil life the frequency is greater, but the mortality less.

In a limited number of cases, though the patient does not die, the recovery is imperfect, the lung being contracted and bound down by adhesions or being the seat of chronic inflammations or tubercular deposits; fistulæ may be persistent; lateral curvatures of the spine may be induced, etc.

The **treatment** of these penetrating wounds consists chiefly in securing rest. Shock, if severe, may necessitate the administration of ether or strychnia by the mouth or hypodermically, alcoholic stimulants being avoided as much as possible. No search for a lodged ball should be made; if it can be felt in the chest-wall, it may be removed at once or left undisturbed for some days until the track may have so far healed as to ensure protection against any possible infection of its deeper part. Any bleeding vessel that is in sight should be tied. The wound or wounds should be thoroughly cleansed and closed with sterilized gauze, and then the chest immobilized as far as practicable and rest as absolute as possible maintained. Lately it has been advised to effect immobilization by the application of the plaster-of-Paris jacket, and a series of twenty successful cases of pistol wounds thus treated has been reported from the City Hospital of St. Louis. The effect of immobilization, in whatever way it may be effected, is, by restraining the movements of the damaged part, to lessen bleeding, to prevent the occurrence of inflammation, to favor absorption of effusions, exudations, or extravasations, and to secure more rapid healing of the track. If there is troublesome bleeding from an intercostal vessel, recourse should be had to ligation or compression, the ligature being applied directly to the artery or thrown around the rib, and compression made by hæmostatic forceps or by tampon. Similar treatment should be applied, if possible, to a bleeding internal mammary artery; fortunately, wound of this vessel

is very rarely observed. Hemorrhage from lesion of a large external vessel above or below the clavicle should be arrested whenever it can be done by the application of a ligature, and such operation must certainly prove less dangerous hereafter than heretofore (75 to 85 per cent. mortality of the subclavian and axillary ligations); if for any reason ligation cannot be effected, compression must be employed. Hæmothorax, if the accumulation is large and the produced dyspnœa great, may be treated by aspiration, but it certainly is better freely to lay open the chest, remove the clot, and wash out the pleural cavity—treatment imperatively demanded at once if the clot becomes infected, as indicated by the ordinary symptoms of septic infection.

Empyema should always be treated by incision, with exsection of a piece of rib sufficiently large to ensure free drainage. An Estlander operation may be required under conditions similar to those making it proper in cases not consequent upon gunshot injury.

Suppurative inflammations in the mediastinum necessitate prompt and thorough opening of the abscess and careful drainage, any foreign body, ball, bone, or other, lodged in the space being removed.

Should an œsophageal wound be recognized, the patient must be fed through a tube carried into the stomach; but as only two cases of such wound are on record, and one of these is doubtful (Delorme), there is little likelihood of this being found necessary.

Here, as in the extremities, fractures are to be treated largely expectantly, completely detached fragments only being taken away. The sharp ends of a broken rib or clavicle may very properly be taken off with the cutting forceps. In scapular wounds no effort to remove fragments should be made, since such fragments are so generally held in place by periosteal, muscular, or fascial attachments that, protected from sepsis, their reunion may be looked for. If necrosis of the bone, partial or complete, occurs, late sequestrotomy may be safely performed.

Secured from infection, no lung inflammation, properly speaking, will be developed, the reparative changes going on about the track of the ball giving rise to little or no constitutional disturbances and requiring no special treatment. If true pneumonia is lighted up, it must be cared for in the ordinary way, as also any localized suppurations or gangrene.

Hernia of the lung, should it be present, necessitates return of the protrusion, and its retention by an appropriate compress and bandage. Such complication, which may occur at once through the wound or later under the skin because of imperfect closure of the opening in the chest-wall or of yielding of the cicatrix, has always been of extreme rarity, and is very unlikely ever to be associated with wounds made by the small bullets of the present time. The same is true of omental and intestinal protrusions, which have been known to occur when a shot has passed through the seventh, eighth, or ninth intercostal space, especially the latter, and the diaphragm has been wounded, particularly on the left side.

In civil life a proper antiseptic treatment will almost certainly be followed by speedy recovery in cases not necessarily fatal from the character and extent of the wound; and the same may be hoped for in military practice in proportion as it is possible to institute and maintain such treatment.

HEART.—These injuries, of not very frequent occurrence and still

less often coming under treatment because of their great primary mortality, are either contusions, openings of the pericardium, or penetrations or perforations of the heart itself.

Contusions must generally be consequent upon the impact of a missile the velocity of which is almost spent, though even then there may be force enough left to cause a laceration of the heart or of its envelope.

Opening of the pericardium without visceral wound can be caused only by a tangential blow, and its diagnosis must commonly remain doubtful.

Penetration of the organ with lodgement of the missile (almost certainly in the ventricular wall or septum, occasionally in the cavity) will be met with only in pistol-ball or small-shot injuries, the bullet of the service rifle always perforating.

As might be expected from the anatomical relations of the parts, wound of the pleura with or without wound of the lung very generally accompanies the heart wound.

Though the **prognosis** is very grave, yet life may be prolonged for days, weeks, or even months (over three years in a case personally observed [1]), a blood-clot or contractions of the muscular fibres closing the wound until organic union can be effected. Fischer found in the cases analyzed, 72 in number, 16 per cent. of recoveries, a percentage doubtless much higher than it really is. In the cases that do not quickly die a heart lesion, pericardial or endocardial, almost certainly remains. The chances of recovery are much greater in wounds of the ventricles than in those of the auricles, injury of the right ventricle being less dangerous than that of the left.

Whether penetrating or perforating, it matters not—for ordinarily the one class of injuries cannot be diagnosticated from the other—the symptoms of these wounds are those of profound shock and collapse, with great irregularity of the pulse and alteration of the heart-sounds, the bruits being confused and confusing. In the case mentioned of extraordinary prolongation of life they were of the most bizarre character, blowing, churning, rasping, altogether unlike those ordinarily heard. There may be considerable hemorrhage from the wound, or, as often happens, the blood may accumulate in the pericardium, by its pressure much enfeebling the heart's action. When there is such pericardial extravasation there is a much increased area of dulness on percussion; the opposite condition of exaggerated resonance has been noticed in a few cases in which there was an accumulation of air in the cavity. Very rarely has a suppurating pericarditis been observed.

The **treatment** should be directed toward relieving shock, arresting hemorrhage, and controlling the heart-inflammations, the wound being antiseptically closed and the chest immobilized. When there is a disturbing amount of blood in the pericardium, paracentesis should be employed, or, better, free incision of the sac—an operation which cannot materially increase the existing danger and may prove of great benefit. Suturing of the wound in the heart-wall has been proposed; it is not likely to be often done.

ABDOMEN.—About 1 in 30 of those wounded in the wars of the last half-century and 1 in 9 of those killed in action were shot in the abdo-

[1] Reported in *The Clinic*, Cincinnati, 1876, x. 253.

men. In approximately equal proportion the wounds have been found to be of the parietes outside the peritoneum and intra-peritoneal, penetrating or perforating. Hereafter the army bullet will almost certainly go through, the only foreign bodies lodging being pieces of cloth or other substances accidentally carried in. In civil practice the deep wounds are much the more common, certainly so as cases present themselves in hospital, and their ratio to the whole number of gunshot injuries is higher; very possibly, however, their universally recognized gravity causes them to be more generally brought under such care.

Of the extra-peritoneal wounds a few are contusions, but in the great majority the missile has either entered and lodged or passed through the wall without damaging the serous membrane. Contusions have become less and less common as improvements have been made in weapons and powder. Generally produced by spent shot, they are very apt to be complicated by visceral lacerations, which have caused death in from one-half to two-thirds of the whole number of cases. In the milder injuries muscle-rupture has been frequently observed, and gangrene of the damaged area with after-suppurations in the wall. When internal lesions are not present the treatment is a simple antiseptic one, with as absolute rest of the parts as can be secured; but if because of profound shock and collapse there is good reason to believe that visceral rupture has occurred, laparotomy should be done, though the prospect of saving life is but slight. In civil life these contusions are very unlikely to be met with.

When the missile has merely passed into the wall, whether it stops or goes out, the wound produced is an ordinary flesh one, the dangers of which are hemorrhage and septic infection. Foreign bodies, if they can be located, should be extracted, though there is not now the same necessity for finding them as in former times; bleeding, if severe or persistent, as it often is, should be arrested by ligation of the vessel, free incisions being made if required; and a most careful antiseptic dressing should be applied. Under such treatment there is no good reason why healing should not very generally and readily take place, and the mortality-rate be decidedly reduced from the 8 per cent. or more of our late war. When the injury produced by the shot has been an extensive one, there is much liability to the after-development of ventral hernia.

The wounds of special interest are those in which the peritoneal cavity has been opened. In perhaps 3 per cent., or even 5 per cent., of these the viscera have escaped injury,[1] but the probabilities in any given wound that serious damage has been done are so great that it should be assumed as a fact that such has been the case—certainly so if the ball has passed from side to side, the antero-posterior wounds only being those in which the organs may escape. The intestinal tract is the part most likely to be wounded, the small intestines being damaged four times as often as the large; then follow in order of frequency the liver, the stomach, the kidney, the spleen, the pancreas. Of any 100 such wounds as they occurred in 1861–65, there were 64 of the intestines, 17

[1] Reclus and Noguès found this condition existing in 1 out of 38 experimental shots; Senn, in 4 out of 14; in 30 laparotomies tabulated by MacCormac simple penetrating wound was twice found; Senn observed it in 2 of his 6 cases of operation (in one of which there was a piece of cloth in the cavity), and Reclus and Noguès report it as present in 17 out of 123 collected cases of shot and stab wounds.

of the liver, 7¾ each of the stomach and kidney, 3 of the spleen, and ½ of 1 of the pancreas. Almost certainly the lesions are multiple, of the hollow viscera, of the solid, of the omentum or mesentery, of the lung, of the great vessels, etc. The number of intestinal perforations averages between 4 and 5, and has been known to reach as high as 16 or even more.

The extent of damage to any viscus is very variable, an apparently explosive action being at times observed in the solid viscera, and even in the stomach or intestine when full of fluid.

The general mortality has been very high, its rate being in our war 87.2 per cent., and in various wars, as tabulated by Otis, 75.1 per cent. Even in the less grave injuries of civil life caused by pistol balls the death-rate has until recently been generally much above 50 per cent. In the Chambers Street, the New York, and the Roosevelt hospitals, in the years 1876–84, of 23 cases treated conservatively 15 died—65 per cent. (Stimson). In the five years immediately preceding May, 1887, of 32 cases in the Charity Hospital of New Orleans, 19 died—59.4 per cent. (T. G. Richardson). Of 91 cases collected by Reclus and Nogués, but 22 died—24 per cent. As we shall see later, the average death-rate of cases operated upon during the last ten years has been about 66.2 per cent.

This very heavy mortality has been because of shock, of hemorrhage, and of septic inflammation—of the latter in those cases in which life is prolonged beyond a few hours. The organisms causing such inflammation may be introduced from without (chiefly on the fingers of those who handle the wounded man or upon the instruments of the surgeon), are present in the discharges from the intestinal canal, have been carried to the damaged area in the blood-stream, or have passed through the unwounded bowel. Shock must remain as heretofore, but under modern methods of treatment hemorrhage can be largely controlled by ligation, and the introduction of pyogenic bacteria from without be prevented, or their deleterious influence when introduced from within in some measure lessened by thorough cleansing of the soiled cavity and closure of the visceral wounds. In both hollow and solid viscera there must hereafter be less damage done by the small-calibred bullet than was formerly caused by the large, often deformed, minié ball, at least outside the zone of explosive action.

The mortality of wounds of the several viscera varies within rather wide limits. As observed in 1861–65, it was of the liver 63.5 per cent., of the kidneys 66.2, of the stomach 75.9, of the pancreas 80, of the intestines 89.4, and of the spleen 93.1. Of 50 cases of kidney wound studied by Edler, the mortality-rate of the 20 uncomplicated wounds of the organ was 25 per cent., and of the 30 in which there were associated wounds of importance 44 per cent.; of 42 wounds of the spleen 83.37 per cent. died. In the pistol-shot wounds of civil life, though the present fatality of each of these visceral lesions is decidedly less, there is still a marked difference between them, the prognosis of injuries of the stomach or of the large intestine being, as it always has been, much more favorable than of those of the small intestines. In all of the wounds of the alimentary tract, those received when the stomach or bowel is empty are less dangerous than those received when it is full.

The **diagnosis** of penetration, at times easily and definitely established, is not seldom very uncertain in default of an opening up of the track of the ball or an abdominal section. If through the external wound there is an escape of intestinal contents or of bile, or protrusion of bowel, omentum, or portion of a wounded solid viscus, there can be no question respecting the opening of the cavity. But such positive evidences of penetration are afforded in but a minority of cases. The presence of even small quantities of the intestinal contents in the peritoneal cavity has been comparatively rarely noticed in pistol-shot wounds operated upon, much less often have such matters been discharged externally; and the same will doubtless be true of the injuries caused by the new bullet. The openings are often so small that they are plugged by the pouting mucous membrane or closed by changes in the parallelism of the coats of the bowel or by the adhesion of adjacent coils of intestine or omentum. Sometimes the fecal extravasations have occurred only after the lapse of some hours or even days (because of the primary paralysis of the bowel), at a time, therefore, when this diagnostic evidence is of little practical value. Escape of bile, indicative of liver-wound, may be expected to take place in but about two-fifths of the cases of injury of that organ, only probably in those affecting its central part, and in but a portion of these cases will it flow out through an external wound. Hernia, whether of intestine, omentum, or of a portion of a damaged solid viscus, very rarely occurs, and is not to be expected in wounds made by pistol balls or the small-calibred rifle bullet. Otis found but two instances of bowel protrusion reported to the Surgeon-General during our war, a number without doubt much smaller than that of the cases actually occurring. One such case, of which no record appears in the *Med. and Surg. History*, came under personal observation during the siege of Port Hudson, the protruding knuckle of small intestine showing perforation wounds.[1]

As a rule having few exceptions, the **diagnosis** of penetration will have to rest upon observation of the position of the wound—or, better, wounds, the ball having gone through—upon hemorrhage from the stomach or the bowel, blood-stained vomited material, extreme shock, collapse indicating hemorrhage in considerable amount, or, after the lapse of days, the discharge of the ball at stool. Neither shock, nor vomiting of blood or blood-stained mucus, nor bloody stools positively indicates penetration of the stomach or bowel, as either may possibly be consequent upon contusion; but the occurrence of these symptoms in connection with the location of the wound makes the diagnosis very

[1] In 1872, Asst. Surg. Patzki, U. S. A., reported to the Surgeon-General from Fort Clark, Texas, an accidental wound made by the ball of a Derringer pistol, cal. .36, at 1 foot distance, the shot entering 1½ inches above the umbilicus, ¼ inch to the right of the median line, and lodging, its location being undetermined: 2½ inches of the omentum protruded. On the seventh day after the injury this protruding omentum was removed with a wire écraseur. It was at the time "firmly adherent to the sides of the wound, thickened, more solid (carnified), covered with granulations secreting offensive pus. Patient's condition very good. Vomiting after injury, but no blood in the vomited matter or stools. The protruding omentum, being useful as a plug, closed wound hermetically. No attempt made to return it. No symptoms of internal hemorrhage, fecal extravasation, or peritonitis. Expectant treatment." Recovery rapid; wound cicatrized eleven days later. Returned to duty twenty days after receipt of injury, bullet still remaining in the body.

probable. A ball passing from side to side at or below the level of the umbilicus, at such depth beneath the highest point of the curve of the abdominal wall as will more than carry it through the thickness of the wall, must certainly wound the intestines. When Senn in 1888 reported upon the results of the experimental rectal insufflation of hydrogen gas, it was hoped that there had been found a sure and safe method of establishing the diagnosis of bowel-wound. Hydrogen gas slowly and continuously introduced under a pressure of from ¼ to 2 pounds was shown to pass the ileo-cæcal valve and traverse the entire length of an uninjured alimentary canal, while if there was a wound at any point it would escape through such, distend the abdominal cavity, obliterating the liver-dulness, and find its way out through the external shot-opening, as proved by its ignition when a flame was brought near such opening. Unfortunately, experience has shown that the test is not always reliable, the passage of the gas being at times obstructed by fecal accumulations in the lower bowel, or its escape externally being prevented by adhesions, ordinarily omental, at the inner opening of the track through the abdominal wall. When, then, there is serious question of there being penetration, the wound should be carefully laid open until it is clearly shown that it does or does not involve the peritoneum. If the shot has passed transversely, the cut may be made in the middle line, when, if the wound is extra-peritoneal, its track will be crossed before the peritoneum is reached. It is never wise to explore the track of the ball with a finger or, much more, a probe, since penetration may thus be made in cases in which the serous membrane has not been pierced, or adhesions may be broken up or hemorrhage excited.

Kidney lesion is established as a probability by shock, the direction of the course of the shot, and the discharge from the bladder of bloody urine, though the latter symptom may be present in connection with ureteral contusion or laceration, or with injury of the bladder itself. When the wound is from behind, the visceral wound may be altogether extra-peritoneal, and urine may escape externally or into the tissues about the organ. If there is associated penetration of the peritoneum, there may or may not be extravasation of urine into the abdominal cavity.

As shown by Redard in 1870, grave lesion of the contents of the abdominal as of the cranial and thoracic cavities is always to be inferred when there is from the beginning for four, six, or more hours a subnormal temperature.

The occurrence of peritonitis (which if it is developed is almost certain to be so in from eighteen to thirty-six hours) is indicated by the ordinary symptoms of the disease, the marked acceleration of the pulse (it is often very great) being of much more diagnostic value than the temperature-changes, which are frequently but slight.

Treatment is either by abstention or by operative interference. Up to a time not fifteen years ago surgeons generally were content to apply cold; to put on a bandage, even of plaster of Paris (Neudörfer); to maintain rest as absolute as possible; to feed sparingly, and that with fluids; and to administer opium, given at times with so free a hand as to make it questionable whether the fatal result was due to the injury or to the treatment. But the death-rate was so high that not a few were dissatisfied

with the course adopted. Sims had advised laparotomy that bleeding vessels might be found and tied, and Bahr had recommended that on the battle-field the wound of the abdominal wall should be laid open and enlarged, the cavity cleansed of fecal matter, and the wound of the bowel closed by suture. Otis had protested against the "do-nothing system," and McGuire had urged operation, declaring that if such measure was a desperate one the peril was so extreme that under the usual treatment nearly all the patients died. In 1881, Kinloch did an exploratory laparotomy and closed three perforations; two years later Kocher by a similar operation saved the life of his patient, and in 1884, Bull was equally fortunate, his case being the first successful one in our country. In the same year Parkes as chairman of the Surgical Section reported to the American Medical Association the results of many experiments upon dogs, and advised and urged direct operative interference in all intra-peritoneal wounds. Since that time the question has been not whether the abdomen should be opened and lesions treated surgically, but in what cases it should be done—or, rather, whether or not it should be done always and as soon as possible. To answer this question it must be known what are the probabilities of recovery when operation is not done, and what have been the results of the sections that have been made.

It has already been stated that in three of the New York hospitals 65 per cent. of the cases treated expectantly during the years 1876–84 died; in the Charity Hospital of New Orleans, in five years prior to May, 1887, 59.4 per cent. died; and of 91 cases collected by Reclus and Noguès, largely from journal reports, but 24 per cent. died. Reclus has lately reported that of 114 revolver wounds of the abdomen treated expectantly 94 recovered—82 per cent. The experience of surgeons generally has been such as to make them unwilling to accept these figures of Reclus (24 and 18 per cent. of mortality) as representing the ordinary death-rate at the present time of the wounds under consideration when properly treated by abstention. If they do, such treatment is very much better than that by operation. It is very probable, though, that the ordinarily stated mortality-rate is too high, and would be found to be much lowered in the practice of those willing to carry out fully and faithfully the strictest antiseptic method, and capable of doing so.

Of the death-rate after operation we can now speak quite definitely. It was, in the cases collected by Körte, 65.6 per cent. (64–42); by Reclus and Noguès, 78 per cent. (73–57); by Morton, 67.27 per cent. (110–74); by Barrow, 66 per cent. (112–74); by Martin and Hare, 66⅔ per cent. (129–86); by Coley, 67.27 per cent. (165–111). Personal reports from fifty-five of our American surgeons of all their cases give a mortality-rate of 70.66 per cent. (174–123). Twenty-three had operated but once, with a death-rate of 82.6 per cent., nine twice, with death-rate of 95 per cent.; eight had each seven or more cases, aggregating 82 with 50 deaths—61 per cent. Here, as in other abdominal operations, with increased experience come better results. In no small measure certainly this larger percentage of recoveries is due to more rapid operating, the time of exposure of the abdominal organs being a very important factor in the case. As shown by Martin and Hare, an operation completed in an hour is three times as likely to be followed by recovery as one completed in two hours. Of necessity, much time must be taken,

but it need not be on an average an hour and three-quarters, as stated by Delorme. The tedious part of the operation is the finding of the perforations and making sure that they have all been found. Inch by inch the small intestine must be examined, either laid out upon the abdominal wall (protected by hot sterilized gauze or towels) or, much better, returned to the cavity as fast as it has been inspected. Proper search must also be made for any wound of the stomach, the large intestine, or the bladder, and the presence or absence of a lesion of liver, spleen, or kidney determined. All this takes time, and time means risk, and not seldom, notwithstanding the time taken and care exercised, a perforation or perforations have been overlooked by the best of surgeons. Insufflation of hydrogen has at times proved of much service, being injected from opening to opening from below upward. In place of hydrogen, atmospheric air may be used. Could the gas or air be always relied upon, and did not its use expose to the risks of forcing open perforations already closed and of expelling fecal matter into the peritoneal cavity, it would be of extreme value because of the rapidity with which the wounds can be located.

The necessary manipulations of a laparotomy must now and then be the cause of the breaking up of already-formed protective adhesions of bowel to bowel, of bowel to omentum, or of bowel or omentum to the abdominal wall.

The earlier the section is made the better, that bleeding may be arrested and fecal extravasation prevented, or, if it has occurred, that the exceedingly irritant matter may be removed before it has had time to exert to the full its deleterious influence. All observation has shown that the chances of recovery rapidly diminish as the hours go by, the patient comparatively seldom surviving a laparotomy done a half day or more subsequent to the shooting. When peritonitis is fully developed, death is almost sure to occur, but as once in a while relief is afforded by operation, the section may properly be made.

In civil practice laparotomy should always be done, and that at once—

1. When there is positive evidence of penetration in the protrusion of bowel or omentum, though occasionally recovery may take place without section after return of the protrusion or, if omental, its removal at the time or later;

2. When there is discharge externally of fæces, bile, or urine;

3. When severe and rapidly-developed collapse shows that a large vessel (or vessels) has been torn;

4. When the wound has been made by a bullet of other than small calibre, particularly if it is at or below the umbilical level, and especially if the shot has passed from side to side.

In field service it will be quite difficult, and often altogether impossible, to treat these wounds actively; and, as military necessities may compel at times an early removal of the wounded, this of itself will render a successful termination of an operation much less probable than after similar work in a well-organized hospital.

When the injury has been inflicted by a small ball of calibre not above .22, and affects probably only an empty stomach or the colon or one of the solid viscera, operation may very properly be postponed so long as neither local nor constitutional symptoms of severity are present.

Though stomach wounds made by a large bullet are among the graver abdominal lesions, from three-quarters to seven-eighths of them in 1861–65 and 1870–71 dying because of hemorrhage or extravasation of the contents of the organ, they may be expected to be much less dangerous when produced by the present army bullet, unless received within the zone of explosive action. As met with in civil life, where they are often caused by small bullets, a considerable proportion may be recovered from either with or without operation. The same is true of liver-wounds, in many of which the diagnosis without section is quite uncertain: the track is small, the bleeding is not excessive, jaundice very rarely occurs (not in one in twenty cases probably), even a lodged ball may be well borne, and if bile escapes into the peritoneal cavity it is very much less irritant than was formerly supposed. Kidney-wounds, if made from behind and not complicated by intra-abdominal lesions, may be treated expectantly, unless the hemorrhage is great or there is urinary infiltration of the surrounding tissues, when the organ should be cut down upon, ligation if necessary done, and free escape of the urine secured, or, if the organ is much injured, nephrectomy performed. There is doubtless much wisdom in Tiffany's suggestion to treat the kidney-wound like any other, suturing it, draining it, and removing so much of the viscus as has been disorganized, remembering that if necessary the whole kidney can later be taken away, and that with less risk than attends a primary operation. Often wounds of this organ are complicated with those of the liver or the vertebræ.

The technique of laparotomy for gunshot injury is in the main that of the operation for other causes. Incision, as a rule having few exceptions, should be in the median line, and not through the wound, as thus more ready access may be had to all parts of the abdominal cavity. Bleeding should be first attended to, clots removed, the source of the hemorrhage discovered if possible, and the wounded vessels tied. At times an intercostal artery or the internal mammary has been wounded, and not seldom one of the large vessels of the pelvis; but in very many cases the bleeding is from the mesentery or from one of the solid viscera. If active bleeding is going on, it may be temporarily controlled by compression of the aorta or by gauze compresses, so that the parts may be rendered dry enough to permit of the vessel being seized and tied.

The alimentary tract is then to be examined. All openings in the bowel should be stitched up, except those so large that their closure must be followed by marked constriction, or the very small ones that are already plugged by the everted mucous membrane, which may be left to themselves if the general condition of the patient compels quick completion of the operation. Fine silk is far the best suture material. Contused patches, if the injury is other than slight, had better be treated as if they were open wounds, or they may be covered with an omental graft, which latter is often of service in giving additional protection to the sewed wound. The ordinary Lembert stitch is commonly employed, and as far as possible the seam should be made transversely. When the wounds are too large to be safely sewed up, the damaged section of the bowel must be excised, and either end-to-end or lateral anastomosis effected, preferably the former as a rule. If lateral anastomosis is made,

excision of the lacerated bowel need not necessarily be done. Plates or buttons may be used, though they are not necessary. Mesenteric openings should be closed and any bleeding mesenteric vessel ligated, either catgut or, better, fine silk being employed. If there has been any considerable laceration of the omentum, the damaged piece should be tied off and cut away.

An existing wound in the liver should be sutured if it can be done; if not, plugged with gauze, a drainage-tube (preferably of glass) being used if necessary. It has been advised to always take away a badly-damaged kidney, but partial removal will doubtless often be found sufficient. Lesions of the spleen, if much disorganization has not been produced, may be treated simply; when the tearing has been great splenectomy is certainly indicated, in default of which plugging must be resorted to—a method of treatment which must be used if there is a wound of the pancreas.

Cleansing of the abdominal cavity should be very thorough, and it is in this part of the operation that much time is often consumed. The closure of the external wound is effected in the usual way, a drainage-tube being used when there has been much bleeding or much soiling of the cavity with alimentary matters.

The patient must be kept quiet; shock relieved by the administration hypodermically of ether or strychnia (hot-water douching of the cavity is of great value in relieving shock temporarily while the operation is in progress); fluids withheld as far as possible for at least twenty-four hours; and after that for several days an absolute milk diet observed, milk, besides its value as a food, having been clearly shown to have a decided germicidal action. As after the more common laparotomies, the administration of saline cathartics is of service in relieving gaseous distention and preventing peritonitis.

In a limited number of cases (very rarely, however, in civil practice) fistulæ have followed abdominal wounds, almost always in connection with the large intestine. The spur so often observed in artificial anus after hernia has been very infrequent. Generally these fistulæ have closed spontaneously in the course of a few months. If such closure does not take place, they should be operated upon in the usual way.

Rectum.—Wounds of the rectum may be in connection with those of the bowel higher up, of other pelvic organs, of the bones of the pelvis, or of the perineum and parts adjacent. In themselves they are of interest chiefly because of the extensive suppurations and gangrenes so often consequent upon fecal extravasations through them. When such infection of the connective tissue does not occur, the uncomplicated wound heals rapidly, and, if made by pistol ball or small-calibred bullet, without after-fistula or stricture.

Even the necessarily more or less defective antisepsis that can be secured in military practice will doubtless be sufficient to decidedly reduce the former mortality-rate of wounds of this kind received in action (between 40 and 50 per cent.); and it may reasonably be expected that in the perforating injuries that will be made by the new bullet there will be less laceration of the bowel and less likelihood of extravasation, and probably better drainage of the damaged area.

If the rectal wound is but one of several intraperitoneal lesions, if it

can be gotten at it should be stitched, otherwise the gauze tampon must be employed. A pistol-ball injury below the peritoneal reflection will make necessary only careful cleansing and disinfection of the bowel and the observance of the ordinary rules of wound-treatment; and the same is true of any uncomplicated lesion higher up. After the lower bowel has been well washed out with an antiseptic fluid, the more quiet it is kept the better. Surgeons have long recognized the beneficial effects of the internal administration of opium given in dose sufficient to constipate. If because of infection ischio-rectal inflammation occurs, free incisions must be promptly made and an antiseptic treatment thoroughly carried out.

BLADDER.—Bullets passing into or through the pelvis not seldom wound the bladder—much more frequently, of course, when the viscus is full than when it is empty. These shots may come in any direction, and very generally they injure some part of the bony wall. Not necessarily so, however, for they may enter from above or from below and lodge in the pelvic cavity, or they may pierce the anterior inferior abdominal wall just above the pubes and emerge through a sacro-sciatic foramen. Their course usually is antero-posteriorly with more or less obliquity, though the bladder may be damaged by a ball passing from side to side, rarely, however, if it is empty. Sometimes the vesical wall is so pierced as to prevent escape of urine in any considerable amount, and gutterings without penetration may take place, the ball track ordinarily, however, soon opening up by ulceration.

In the large majority of cases the lesion is a complicated one, the rectum being commonly wounded when the direction of the bullet is from behind forward or from before backward, unless the momentum is so slight that the shot lodges against or in the anterior wall of the bladder or in its cavity. In not a few of the cases there is in association so serious a lesion of the blood-vessels of the region that death quickly occurs from hemorrhage. The wound may be in a part of the bladder covered with peritoneum or may be extra-peritoneal, the gravity of the case being much greater when in the former situation, extravasated urine finding its way into the abdominal cavity instead of into the connective tissue. It is to such extravasation with its resulting septic infection that death is commonly due in cases not fatal from bleeding or from associated visceral lesions.

The mortality-rate of cases coming under care in military practice has been about one-half (45–55 per cent.), but of those in civil life early and properly treated it is decidedly less, very much so when the bladder was empty at the time of its injury.

The **symptoms** are—shock, pain in the region or diffused over the abdomen, and general weakness, each commonly in high degree; much irritability of the bladder and rectum; hæmaturia; and escape of urine through the external wound, either persistently or intermittently according to the low or high location of the opening. The last two symptoms are of great diagnostic value, though the presence of blood may be consequent upon contusion of the bladder or upon wound of some other part of the urinary tract, and leakage of urine may possibly come from lesion of an ureter or the urethra, and whatever its origin it is actually met with in but a limited portion of the cases of wounds caused by pistol or

small-calibre rifle balls. When there is an associated opening of the rectum fecal matter may be discharged with the urine or the urine passed through the anus. Voluntary micturition may be possible or catheterization required; in the latter case it is advantageous for every reason to keep the catheter in, rather than to introduce it at stated periods or as necessary. Sometimes so much blood accumulates in the bladder that aspiration will have to be done. When there has been discharge of urine into the abdominal cavity, certainly in any considerable amount, symptoms of peritonitis or of grave septicæmia are rapidly developed, the latter at times so quickly fatal that upon autopsy no evidences of inflammation are to be seen. Left to itself, a case of this kind is certain to die. When urine is extravasated into the connective tissue in front of the bladder or into the meshes of the recto-vesical fascia, abscesses soon form or, by contiguity, peritonitis is induced. The progress of these cases of bladder-wounds illustrates the truth of Bichat's declaration that "urine is the most baleful fluid in the economy;" if not so when of normal quality, unquestionably so when in the presence of blood and air it has become septic.

Treatment varies as the lesion is intra- or extra-peritoneal. In the latter case a catheter may be introduced and retained and the patient treated expectantly. But unless, from the location of the wound or wounds and the direction of the shot, it is very certain that the injury is outside of the peritoneum, laparotomy should be done at once, the abdominal cavity cleansed, and the wound in the bladder stitched; and if there is any doubt about the nature of the injury, suprapubic section should be made and the prevesical space, if not the abdominal cavity, opened up. Any wound should be stitched, the parts cleaned and disinfected, and drainage secured, preferably by a gauze plug. If a foreign body, ball or bone, has lodged in the bladder (and such lodgement has taken place in a disproportionately large number of vesical wounds), it should be removed at once if a laparotomy or a suprapubic section has been done, otherwise it may be taken away through a perineal opening either early or after the wound in the bladder has healed. Occasionally there has been an extraordinary tolerance for months or years of the foreign body. In a number of cases the ball or bone, or even a piece of cloth, in the bladder has served as a nucleus upon which the phosphates have been deposited and stone formed. When the ball has been lodged externally, it has been known to ulcerate its way into the bladder after a time, years even, and then require removal; and the same has been true of pieces of bone, fragments detached at the time of the injury or later separated by necrosis. Otis reported twenty lithotomies done on account of such injuries received during our late war. Very small balls have at times been spontaneously discharged through the urethra.

In the beginning of the treatment, whether operative or otherwise it matters not, fluids should be given very sparingly. Rest as absolute as possible should be maintained. Any abscess that can be located should be promptly opened. In favorable cases healing may be expected to take place in from three to six weeks. In many of the cases heretofore observed in time of war in which death did not speedily follow, recovery was very protracted and imperfect, bone-sinuses or urinary fistulæ remaining; but such sequelæ are not likely to be frequently met with hereafter.

in either military or civil life, because of the changes both in missiles and in treatment, especially the latter.

GENITAL ORGANS.—Injuries of these organs, rare in civil life, not very uncommon in military practice, may be either superficial or deep; occasionally they are contusions, generally penetrating or perforating wounds, in a few instances extensive destructions. Associated injury of thigh or abdomen is of frequent occurrence, and to such complication death, when it takes place, is usually due (of 1152 wounds in our war, 144 died—12.5 per cent.).

Superficial wounds of the penis or scrotum are injuries of little gravity and require no special treatment, any produced hæmatocele or hernia of the testis (conditions at times observed) differing in no respect from that consequent upon ordinary traumatisms. Occasionally there has been lodgement of a ball, even of large size, under the skin, the removal of which has been easy; in certain cases in which it has not been taken out it has become encapsulated and remained harmless for years, though its presence is likely to be troublesome.

The corpora cavernosa when perforated always show considerable laceration, and the same is true of the glans penis. Very generally the urethra also is torn, in which case, unless proper treatment is pursued, urinary infiltration and abscess are apt to be produced. As late results of these wounds of the penis there have been seen troublesome and deforming cicatricial contractions of the organ, strictures, and fistulæ, penile, scrotal, or perineal according to the location of the wound.

Primary treatment has reference to the arrest of hemorrhage, the securing of prompt closure of the wound, and the prevention or relief of urinary retention. Bleeding, which is apt to be quite free, may be controlled by the stitching of the edges of the wound together, by ligation of any divided vessel seen, or by pressure, a catheter being introduced and a bandage applied around the organ. Protecting the wound from infection by the use of an ordinary antiseptic dressing will commonly secure its prompt healing. To prevent urinary disturbances (retention or infiltration) the bladder must be kept empty by a retained catheter, the edges of the urethral laceration being stitched over it if practicable, or if the loss of substance has been great the wound allowed to close by granulation. Much benefit will often follow perineal section and the turning of the urine through such opening.

No matter how much the penis may have been damaged, it is ordinarily unwise to amputate; any part of it that can be saved should be saved. If the entire organ has been carried away, the urethra should be dissected back and a new meatus established in the perineum if the patient's general condition permits of the operation.

In other than the most superficial wound of the scrotum the testis or cord may be expected to be injured; in a third of the cases studied by Fischer both testes were struck. The damage done the gland by a bullet except at short range is rarely such as to necessitate its removal. Hernia of the testis, formerly often seen in cases of lesion by a large ball, is very unlikely to follow pistol shots or wounds by the new bullet, but atrophy of the organ has been frequently noticed, as has more or less persistent, and often intense, neuralgia. Antiseptically treated, suppuration ought not to occur—a complication that until lately was almost

certain to be developed. When both testicles have been disorganized they should be removed, and the wound closed by a short scrotal flap if there is enough healthy tissue left to allow of its formation.

Wounds of the female genitals are rare, and they are usually in association with grave abdominal or pelvic lesions. In the very infrequent cases in which they are inflicted at very short range the laceration that takes place is extensive. In a case personally observed in which the muzzle of the pistol was thrust between the labia the combined effect of the bullet and the gases of explosion was to destroy almost completely the vagina and the uterus. A ball passing through the unimpregnated uterus ordinarily does comparatively little harm, but where pregnancy exists there is much risk of an early fatal termination from abortion (almost certain to take place), from hemorrhage, from shock, or from septic inflammation. In certain cases which have survived, fistula has been noticed, giving passage to the menstrual fluid for a time or permanently.

Sword and Bayonet Wounds.

Wounds of this character have been rarely seen in recent times—.37 per cent. only of the grand total of wounds in 1861–65, 1.3 per cent. in 1870–71, .9 per cent. in all the wars from the Crimean to the Franco-German, both included (437,636–4890). They must probably be much less frequent in future military operations; the new magazine rifle, that will disable if not kill at a mile, a mile and a half, or two miles' distance, preventing any considerable force of either infantry or cavalry approaching sufficiently near to use bayonet or sabre. Surgeons hereafter will, as a rule having few exceptions, see these injuries only as they may result from individual quarrels or in mob-fighting. As made by the bayonet, and, much less often, by the straight sword, the wounds are punctured; by the sabre, when sharp, incised, when with dull edge, as it generally is, lacerated and contused. The bayonet injuries are more common in the lower extremities than elsewhere (46 per cent. of the whole number reported in 1861–65), sabre wounds in the head and upper extremities (89 per cent. in the same war), though the proportionate local frequency has been quite different in different wars. Leaving out of consideration cases dying on the field, the mortality-rate is low; with us it was 7.7 per cent. for the bayonet and 5 per cent. for the sabre wounds, the fatal cases being very largely those in which one or other of the great cavities was opened; of the 712 cases in which they were not opened only 16 died (2¼ per cent.). Aside from visceral lesions and injuries to the large vessels, the chief danger of the penetrating wounds is in the damming up of fluids in their depths and the development of suppurative inflammations; the chief danger of the contused and lacerated wounds is the occurrence of septic conditions.

The appearance of the wound varies as it is made by thrust or by cut, the former being in form slit-like, triangular, or more or less crescentic according to the shape of the weapon; the latter showing a straight cut with more or less contusion and laceration of the edges, or the formation of a flap, or an ovoid somewhat cupped open wound from complete or nearly complete detachment of a flap, which latter in injuries of the cranium may have in it a piece of the skull of thickness according to the

depth of the wound. In wounds involving the larynx, trachea, or lung emphysema is often present, it may be in high degree.

The **treatment** is that of lesions of like character otherwise produced. By thorough cleansing and proper dressing an aseptic condition may generally be secured. Vessel-wounds will necessitate the application of ligatures or not according to circumstances. Detached bone-fragments will have to be taken away. If there is puncture of the skull, trephining should be done. Any foreign body, clothing, hair, or other, that may happen to have been carried in should be removed if its presence can be detected, clothing being especially likely to be lodged in the seton wounds of the soft parts. An existing emphysema, if it does not soon subside spontaneously, will necessitate puncture.

Arrow Wounds.

Once so common, arrow wounds are now seen extremely rarely, and hereafter their consideration will have but an historic value, since among other than the lowest and most isolated tribes of savages firearms have taken the place of the bow. As met with, they were of the nature of both punctured and incised wounds, penetrating, even perforating, the

Fig. 35.

Skull with arrow-head fixed in it, taken from mound in Boone Co., Ky.: *A*, stone arrow-head lodged; *B*, injury accidentally done by pick at time of removal.

body, their tracks through the tissues straight and clean cut, with entrance wounds somewhat bruised and discolored from extravasated blood, and exit ones (if present) mere slits. Within a range of one hundred yards or less their force of penetration might be very great, depending of course upon the strength and skill of the bowman. Often an arrow was sent through the body of an animal as large as the buffalo, bone being pierced as with the point of a large, strong, sharp knife. Striking a blood-vessel, a nerve-trunk, or an intestine, such part could not glide out of the way, but was certain to be wounded. Severe

hemorrhage was likely to occur. The upper part of the body was much more often injured than the lower, and visceral wounds were of course much the more dangerous. Though, as has been stated, the course of the arrow was straight, when the head was of iron and thin it at times upon striking a bone bent itself around it. From the nature of the missile and the almost necessarily unhygienic surroundings of the patient, these wounds were in great measure infected ones; and so much of the mortality following them as was not due to loss of blood was consequent upon sepsis. When the head had lodged, it was taken out whenever it was practicable to do so, as if left it was certain to cause trouble. Such extraction, when it was separated from the shaft, was often difficult both in the seizing and removing. Snares and forceps of different kinds were employed to facilitate the operation, an excellent instrument which combined the qualities of both snare and forceps having been devised by the late Dr. J. H. Bill. To him, a distinguished officer of our army who had a long service with troops in the "Far West," we are indebted for much information respecting the nature and effects of arrow injuries. In concluding his article in the *International Encyclopædia of Surgery* upon this subject he sums up his views in the following words:

"(1) An arrow-head must be removed as soon as found.

"(2) In the search for the arrow extensive incisions are justifiable.

"(3) An arrow may be pushed out as well as plucked out.

"(4) The finger should be used for exploration in preference to a probe.

"(5) Great care must be taken to avoid detachment of the shaft.

"(6) Healing by first intention should be encouraged.

"(7) The surgeon should strive to comfort the patient. Although arrow wounds are not attended with much shock, they are usually the cause of great depression of spirits. The constitutional disturbances following these wounds . . . . are liable to be out of all proportion to the apparent amount of damage. There are almost always considerable sleeplessness and great irritability, dejection of spirits, and intolerance of pain. The tendency to despondency becomes frequently a prominent symptom, to be carefully combated, and everything should be done to cheer the patient."

FRACTURES.

By FREDERIC S. DENNIS, M. D.

A FRACTURE is a solution in the continuity of bone or cartilage, produced by violence, muscular action, or disease. The word "fracture" is derived from the Latin verb *frango*, meaning "to break." Epiphyseal separation is also classed with fracture, because the injury is produced by the same causes, presents the same signs, and requires the same treatment. Fractures may be *complete* or *incomplete*.

Complete fractures are subdivided into simple, compound, comminuted, multiple, complicated, and impacted. Some of these varieties may again be subdivided, according to the direction of the fracture, into oblique, transverse, longitudinal, and dentated.

Incomplete fractures may be subdivided into greenstick, partial, fissured, stellate, and spiral.

Epiphyseal separation may be considered as a species of fracture, since the injury involves a tearing away, by a sudden act of violence, of the epiphysis from the diaphysis of the bone, the separation occurring at the cartilaginous line of union. This injury is found only in persons under twenty-one years of age, since after that period the epiphyses are usually united by bone to the diaphyses. The repair is effected by osseous tissue, and as a result the bone ceases to develop at the fractured end. Shortening occurs, which may be very great if the patient at the time of the injury has not attained his or her full height.

A *complete fracture* is one which entirely traverses the bone. A *simple fracture* is one in which the bone is broken at one point and the seat of fracture has no communication with the external air.

A *compound fracture* is one where the bone is broken at one or more points and the seat of fracture has communication with the external air. A compound fracture must not be mistaken for a simple fracture attended by a wound in the soft parts. In the former case the wound is the result of the fracture, and comes from within, while in the latter case the wound is independent of the fracture, and comes from without.

A *comminuted fracture* is one in which the bone is broken into many small fragments (Fig. 36).

A *multiple fracture* is one in which several fractures occur in the same bone (Fig. 37).

A *complicated fracture* is one which is associated with a wound open-

ing into a joint, or is accompanied by an injury to an internal organ, to an artery, or to a nerve, or which coexists with a dislocation.

FIG. 36.

Comminuted fracture of tibia and fibula.

An *impacted fracture* is one in which the fragment consisting of compact bone is driven into the fragment of cancellated bone (Fig. 38).

FIG. 37.

Multiple fracture of both bones of the leg.

FIG. 38.

Impacted fracture of the neck of the femur.

Fractures may be subdivided again according to the direction of the line or plane of separation.

An *oblique fracture*, which is the most common form, is one in which the line of separation is at an acute angle to the long axis of the bone (Fig. 39). A *transverse fracture* is one in which the line of separation

is at a right angle to the long axis of the bone. This variety is found chiefly in children and seldom in adults.

A *longitudinal fracture* is one in which the line of separation is parallel to the long axis of the bone. This variety is rare, and is usually associated with gunshot injuries (Fig. 40).

A *dentated fracture* is one of such a character that the opposing surfaces denticulate with each other, so that the projections of one fragment fit into the depressions of the other fragment.

An *incomplete* or *partial fracture* is one which only partially traverses the bone, as in a fracture of the external table of the skull while the internal table remains intact.

FIG. 40.

Longitudinal fracture of femur.

FIG. 39.

Oblique fracture of the humerus.

A *greenstick fracture* occurs when the bone merely bends. In this fracture a portion of the fibres are broken, while the remainder hold the bone intact (Fig. 41). This may occur as an *intra-uterine fracture* when the soft bones of the fœtus are bent as a result of abnormal uterine contractions, or by external violence, as in consequence of a fall experienced by the parturient woman.

A *fissured fracture* is one in which a linear divison has occurred without any displacement. This variety is seen in the skull, especially over the vertex.

A *stellate fracture* is one which radiates from a central axis, somewhat after the shape of a star. This variety is seen chiefly in the skull, although occasionally it occurs in long bones, like the femur, after a gunshot injury.

FIG. 41.

Partial or green-stick fracture of the radius.

A *spiral fracture* is one in which the line of the break assumes a spiral course. This variety is seen in the bones of the cranium, but it is also occasionally observed in the long bones (Figs. 42 and 43).

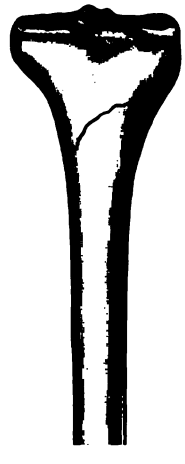
A *gunshot fracture* is one in which the bone is broken as a result of a gunshot wound. This special variety of fracture may be either complete or incomplete.

Etiology of Fractures.—The causes of fracture are *predisposing* and *exciting*. The former include all circumstances which tend to make the bone more brittle, while the latter include all actual or direct forces causing the injury. If a bone fractures without any apparent exciting cause, it is said to be a spontaneous fracture.

Among the *predisposing* causes may be mentioned the influence of *age*, since the tendency to fracture increases as age advances. This is because the bones in the aged are less elastic and more brittle as a result of the loss of organic matter, and at the same time the muscles have lost a certain amount of their elasticity.

FIG. 42.

FIG. 43.



Sex is another predisposing cause, since fractures are found more frequently in the male, with the exception of the intra-capsular fracture of the neck of the femur. This is due to the fact that the female is less active and less exposed to violence.

Season is a predisposing cause, since in winter fractures are much more frequent than in summer. This may be due to the presence of ice.

which increases the liability to bodily falls, and also because the muscles are supposed to be less elastic in cold weather.

The *liability* of certain bones to fracture may be considered a predisposing cause, since the bones upon the right side of the body are more frequently fractured than those upon the left side. This is due to the fact that the right side of the body is used more than the left for the purposes of attack and defence. The bones forming the trunk are less frequently broken than those of the upper extremity, and the bones of the upper extremity less frequently than those of the lower extremity. Again, the long bones are more frequently broken than the short bones. The two individual bones which are most susceptible to fracture are the clavicle and the radius. As to the relative frequency of fractures affecting the different bones, Gurlt's table is here introduced, a study of which affords some valuable information:

Fractures treated in the London Hospitals, 1842–77, Archiv. f. klin. Chir., xxv., 1880, p. 469.

	In Hospital.	Out-patients.	Total.	Per cent.	
Skull	730	27	757	1.457	*Head*, 2002; 3.854 per cent.
Face	732	513	1245	2.397	
Spine	169	3	172	0.331	
Pelvis	139	3	142	0.273	
Coccyx	5	10	15	0.028	*Trunk*, 9067; 17.457 per cent.
Ribs	4784	3477	8261	15.905	
Sternum	45	7	52	0.1	
Scapula	135	290	425	0.818	
Clavicle	382	7458	7840	15.094	
Arm	1064	3020	4084	7.863	*Upper extremity*, 27,119; 52.214 per cent.
Forearm	709	8731	9440	18.175	
Hand	856	4899	5755	16.080	
Thigh	3072	171	3243	6.243	
Patella	649	15	664	1.278	*Lower extremity*, 13,750; 26.473 per cent.
Leg	8067	256	8323	16.024	
Foot	965	555	1520	2.926	
	22,503	29,435	51,938		

Certain diatheses are predisposing causes of fracture, including the results of such diseases as syphilis, cancer, sarcoma, rickets, scrofula, rheumatism, gout, mollities ossium, and mercurialization. Fatty degeneration and senile atrophy are conditions favorable to the production of fracture.

The *exciting* causes of fracture are indirect violence, direct violence, and muscular contraction, which are mentioned in the order of frequency.

In *indirect* violence a force is applied to two parts of a bone, and a fracture occurs between the two points of violence.

In *direct* violence a force is applied to a certain part of the bone, and at the point of impact a fracture occurs. The results of fracture by direct violence are more serious than those by indirect violence, since here is the additional injury inflicted upon the soft parts, and sometimes injury to important organs.

Muscular contraction is the rarest cause of fracture, taken as a whole, although in certain individual bones it is most frequent. The special bones which are most frequently the seat of fracture by muscular con-

traction are the os calcis, tibia, patella, femur, olecranon process of ulna, humerus, and clavicle.

Repair of fractures is considered in the article on Surgical Pathology, and the reader is referred to it for information upon this important subject.

Symptoms and Signs of Fractures.—There is occasionally a slight rise of temperature following the receipt of a fracture, but the elevation is of no special significance. A chill sometimes occurs, but it is nervous and not septic in character, and is of no special importance. Shock also often accompanies a fracture, but this condition soon passes away unless the fracture is compound or complicated.

The first sign of fracture consists of unnatural mobility, or the existence of a false or abnormal point of motion, which is present except in the impacted variety or where the fracture involves certain bones, as the skull or the body of a vertebra. There are different methods of ascertaining the presence of a false point of motion. In fracture of the fibula or radius both hands should envelop the limb, with the thumbs placed over the suspected site of fracture. The alternate pressure of the thumbs will cause the fragments to spring out beyond each other. In fracture of the tibia it is best to hold firmly the upper fragment, and then move the lower one. In fracture of the ribs or of the sternum the palm of the hand can be placed over the thorax and the patient requested to cough. In case of fracture of the thigh or humerus rotation of the limb will demonstrate a false point of motion. The nearer the fracture is to the centre of the bone, the greater the mobility. The mobility is passive in character, and not active.

Another sign consists of rotary displacement of the limb, caused chiefly by its weight, by muscular contraction, and by the violence producing the fracture. In estimating the displacement careful inquiry should be made to ascertain if any previous deformity existed. The amount of displacement is often influenced by the direction of the fracture in the bone.

Still another sign is angular deviation from the normal axis, which is especially seen in the impacted variety caused by great violence. It is absent if one only of two bones in the limb is broken or if the fracture is longitudinal.

Crepitus is a pathognomonic sign, the presence of which can be determined by firmly fixing the upper fragment and moving the lower one. In certain fractures—as, for example, those about the hip-joint—slight rotation of the limb will serve to demonstrate the presence of this absolute sign.

When crepitus is found, it is an unequivocal sign of fracture, but its absence will not exclude the presence of fracture. Crepitus is absent in impacted fractures, in cases of widely-separated fragments, as in fracture of the patella or olecranon, in cases where blood-clots or fascia or muscle intervene between the broken ends of the bones; also after a few days following the injury, at which time the fragments are covered by inflammatory exudations. Finally, crepitus is absent in the green-stick fracture and in the fractures involving the cranial bones. There are many conditions which may be mistaken for crepitus; for example, emphysematous crackling caused by the presence of air in the tissues

albuminoid crepitation, the creaking of tendinous sheaths in thecal inflammations, joint effusions, and bursitis, the grating of osteophytes in rheumatoid arthritis, and the pleuritic friction caused in injuries of the chest. The use of the stethoscope has been suggested with a view to ascertaining the presence of crepitus when it cannot be heard by the ear or felt by the hand.

The presence of *localized pain* and *tenderness* and of *ecchymosis* is an important link in the chain of evidence. The tenderness is present immediately upon receipt of the injury, while the ecchymosis is not well marked until a few days after the occurrence of the fracture. The ecchymosis is due to a hemorrhage from a rupture of the small blood-vessels in the limb, also from laceration of the medulla of the bone. A mottled appearance after a fracture indicates that the source of the blood is from the medullary cavity of the bone. The ecchymosis is more apparent when the fracture involves a large bone or when the fracture is extensive or situated close to the skin. If the extravasated blood extends and causes pressure upon the synovial capsule of a joint, so as to cause irritation, the intra-articular effusion of Gosselin results. The ecchymosis may spread along planes of muscles, and be observed at a point distant from the seat of fracture. This clinical fact is presumptive evidence of the existence of a fracture, provided no contusion is present to explain the ecchymosis. If a wound of the soft parts exists near a fracture, the presence of fat-globules upon it or in the blood indicates the origin of the globules from the medulla, and hence this sign is pathognomonic of fracture.

Shortening of the limb is a sign of fracture when it involves the extremities. The direction of the fracture influences the amount of shortening. A fracture of the oblique variety is usually attended by shortening, while the transverse variety, or a fracture near a joint, is seldom accompanied by shortening. The amount of shortening may be from one to three inches, and in estimating the amount the fact of asymmetry of limbs must not be overlooked, since investigation has demonstrated that oftentimes there is a variation of as much as half an inch in the length of a pair of unfractured limbs. There are a few fractures—for example, of the patella and the olecranon—where lengthening instead of shortening of the bone occurs.

The **diagnosis** of fracture is attended with no difficulty, provided the signs of displacement, mobility, and crepitus are present. The diagnosis, however, may be extremely difficult if inflammatory swelling has taken place, if the fracture is impacted, if its situation is near a joint, if only one of two parallel bones is broken, or, finally, if the break traverses the bone transversely. In these obscure cases it is better to defer the final examination until it can be made under the influence of an anæsthetic and when everything is prepared to adjust some permanent splint. The anæsthetic should not be employed unless the patient's physical condition justifies the use of this measure for the purpose of arriving at a correct diagnosis. In all cases of doubt the injury should be treated as if a fracture existed. In cases where a dislocation coexists with a fracture anæsthesia is indicated, since by this means only can the exact diagnosis be established, the dislocation reduced, and the fractured bone accurately adjusted. In the differential

diagnosis between fracture and dislocation the surgeon must not overlook the fact that in dislocation there is no shortening of the shaft of the bone or false point of motion or unnatural mobility, while in the case of fracture there is shortening of the shaft of the bone, and mobility and a false point of motion exist. A contusion is often mistaken for a fracture, but the absence of shortening, bony crepitus, mobility, and displacement serves to establish the differential diagnosis.

The **prognosis** of fracture depends upon the age, sex, and general condition of the patient, as well as upon the character of the fracture and the special form of apparatus employed. A compound fracture is much more serious than a simple one, and requires three times as long to repair. A gunshot fracture is the most serious of all varieties, and the involvement of a joint adds to the gravity of the case. An oblique fracture requires twice as long to repair as a transverse one.

The **general management** of fractures requires careful consideration. Fractures are a common cause of trouble between the patient and surgeon. The surgeon, to protect himself against a suit for damages, should exercise great care in the treatment of the fracture, and at the same time possess a full knowledge of the principles involved in the management of the special fractures. The former condition requires constant and untiring attention to the patient; the latter, careful study and observation of the injury. When these two conditions are fulfilled, no suit for malpractice can be sustained.

The examination of the fracture should be deferred until the patient is at his home. The patient should at once be placed upon a wire or hair mattress and a firm bed, but never upon a canvas or feather bed. An ordinary hair mattress can be converted into an excellent fracture-bed by placing under the mattress some boards sawed the proper length, to take the place of the springs. In case of fracture of the lower extremity the boots or shoes should be cut off and the trousers ripped up at the seam, to avoid any unnecessary movement of the limb. If suitable splints are not at hand, the limb can be placed in a fracture-box, in which oakum or bran can be used with great advantage as a temporary dressing. A most important procedure is the lifting of the broken limb. This should be accomplished for the lower limb by the surgeon seizing the foot near the toes with his right hand and the heel with the left hand, and then making slow but steady extension in the line of the normal axis of the limb. After full extension in the axis is accomplished the entire limb can be raised to any height. The muscles often resist the surgeon, who should never relax his extension, since by so doing the danger of producing a compound fracture is very imminent. The extension should never be suddenly exercised, but slowly and uniformly, and always in the normal axis of the limb. It is at this time that a thorough examination of the fracture can be satisfactorily made, and its exact seat and direction and its tendency to displacement be ascertained.

In making extension and counter-extension the surgeon must avoid compressing muscles passing over the fracture, distribute the force over a large surface, and extend slowly in the normal axis of the bone. There are often obstacles met with in attempts to employ extension and counter-extension, among which may be mentioned the irregularity of the fracture, interposition of muscles and tendons, tonic contraction of the

muscles, and the presence of splinters of bone. The condition of shock often enables the surgeon to reduce a fracture when it would be otherwise impossible to accomplish the object without anæsthesia. The tonic contraction of the muscles often presents an insurmountable barrier to the reduction of fractures of the extremities. It is of little use to employ an anæsthetic in these cases, and the only sure and certain way to effect a reduction is to perform tenotomy for any or all muscles which resist. This method is not only certain to permit of the easy reduction of any fracture, but the physiological rest thus secured to the fragments is most beneficial, since the irritability of the muscles continues unless the operation is performed.

After the reduction of the fracture is accomplished, the next object to be secured is the retention of the fragments in their proper place. The accomplishment of this object is obtained by suitable apparatus in the form of splints or bandages. Occasionally a limb is covered with phlyctenæ or blebs, which prevent the immediate application of a permanent splint. The use of a fracture-box is indicated until the blebs disappear. The blebs should be punctured with a clean aseptic needle, and the serum thus allowed to escape, and a piece of non-irritating but aseptic gauze should be placed over the site of the vesicle for a few days. In the forearm a bandage should never be placed over the limb in contact with the skin and under any splint, since it may cause undue approximation, or even fusion, of the two bones, and thus prevent the movements of pronation and supination. If any tension exists, cotton should be wrapped around the limb under any splint, since the inflammatory swelling will then less endanger the limb, as the cotton yields and adapts itself to the varying conditions of tension.

(For a full description of the different varieties of bandages and their application the reader is referred to the article on Minor Surgery.)

Compound Fractures.

Compound fractures require immediate and prompt attention. The fate of a patient with a compound fracture often hangs upon the surgeon who first touches it. It should be a rule of practice that antiseptic irrigation should be employed at the station-house or upon the sidewalk before the temporary splint is adjusted, and that at once after the irrigation a clean antiseptic dressing be applied before the patient is lifted into the ambulance to be carried to the hospital or to his home. If no antiseptic solution can be obtained, wash the wound in water that has been raised to the boiling-point and cooled.

The patient having been carried either to the hospital or to his home, the temporary dressing is now to be removed, the fracture adjusted, and the first dressing applied. Too much emphasis cannot be placed upon the point that the *first and aseptic dressing will largely influence the prognosis.* This dressing, therefore, in a hospital should be made in the operating-room, because the germ-laden air of the hospital ward is not a safe place in which to expose a compound fracture. The instruments, sutures, ligatures, drainage-tubes, and everything possibly required for the operation should be immersed in carbolic-acid solution (1 : 40). Several towels wrung out in a solution of bichloride of mercury (1 : 500)

should be prepared for use about the table and around the limb, in order to protect the wound from any possible contact with a surface not rendered aseptic. The wound itself should be covered by antiseptic gauze, while the limb is washed with soap and water, then shaved and irrigated. Upon the limb is then poured a saturated solution of naphthalin in ether or of iodoform in ether. This application removes all the fat, and the naphthalin or iodoform remains as a layer upon the surface and protects the parts.

Having made aseptic all the adjacent parts, the wound itself requires attention. All blood and débris should be washed away by a stream of warm bichloride-of-mercury solution (1 : 4000). The interior of the wound should be thoroughly irrigated with the same solution, and all hemorrhage completely arrested. Loose pieces of bone not attached to periosteum should be removed. The fragments can now be adjusted, and if the displacement is great a silver wire can be introduced to keep them in place. Again, it may be necessary to introduce, besides the wire through the bone, some deep catgut sutures, which are carried through the muscles. Deep sutures are necessary in all extensive and gaping wounds of the soft parts, especially when such muscles as the biceps and triceps or the quadriceps extensor are divided. These sutures must be independent of the superficial set. All fragments of fascia, fatty tissue, muscular shreds, and lacerated integument should be cut away with scissors, and then a final ablution made. A drainage-tube should be introduced into the bottom of the wound, and if the wound is so situated as to drain well, there is no necessity for a counter-opening. Such wounds as just described require free drainage, and counter-opening may be necessary in order to meet the requirements of the case. The tube is then cut off flush with the surface of the skin and fastened by a safety-pin. The wound is now closed by catgut sutures, which completes the operative technique. The towels should now be changed and clean ones substituted, which should also be wrung from bichloride solution. This dressing can be done without an anæsthetic and, as a rule, with little or no pain. When the compound fracture is extensive, it is necessary to administer ether, so that the dressing can be completed from the beginning to the end while the patient is under the influence of an anæsthetic.

A class of compound fractures is often met in which the wound is very small, and with these cases a different plan should be adopted. The irrigation should be made around and in the wound, and then it can be hermetically sealed by sprinkling iodoform upon a small piece of absorbent cotton and placing it over the perforation, and painting styptic collodion over it. This mixture will soon coagulate, the medium of sealing is surgically clean, and then the fracture is ready for the dressings. Thus small wounds can be hermetically sealed, medium-sized wounds closed by sutures and drained through the existing opening, and large wounds drained by a counter-opening and sewed with deep sutures, and the fragments held together by silver wire.

Having completed the operative technique in one of the three ways mentioned, the parts are now prepared for the antiseptic dressing. Iodoform gauze or a small piece of oil-silk protective should be placed over the wound, with a hole cut in it to allow the mouth of the drainage-

tube to drain into the dressings. Iodoform gauze is used, because bichloride gauze irritates the wound. The bichloride gauze is next applied in loose pieces over the iodoform gauze and around the wound. This dressing is moist, because dry antiseptic dressings adjacent to a wound are sources of infection. The loose and wet gauze is held *in sitû* by the application of a moist bandage. Over this deep dressing absorbent cotton is placed and retained by a dry bandage.

This last dressing affords a means of securing equable and uniform compression around the limb and over the fracture. The cotton by its elasticity accommodates itself to the swelling of the parts in the vicinity of the fracture. This part of the dressing is very important as a means of preventing inflammatory swelling and of affording comfort to the patient. Four strips of sheet iron about one inch in width are now adjusted. One strip is to pass down on the posterior part of the limb and over the heel and upon the sole of the foot. Two strips are placed upon the sides of the leg and one upon the front of the leg, and bent so as to conform to the shape of the dorsum of the foot. Over these strips plaster-of-Paris bandages are now applied, and the dressing is completed. These strips prevent any backward as well as any lateral displacement of the fracture, and also do away with the necessity of a heavy splint.

In three days a fenestrum is cut over the wound, and under continuous irrigation the drainage-tube is removed.

The question of how long this first dressing should remain is an important one. Experience has taught that no splint should be left on a limb longer than eight days without an inspection of the compound fracture. The author has seen several bad results arising from a neglect of this rule. In one case a fracture which was skilfully dressed with plaster of Paris was first examined at the expiration of six weeks, during which time the patient's general condition was in every way satisfactory. After removing the splint the bone was found protruding and considerable union had taken place. An osteotomy corrected the deformity, and in six additional weeks a perfectly satisfactory result followed. If this fracture had been examined in eight days after its receipt, the protrusion of the bone would have been detected and the faulty position rectified. While this result is exceptional, such unfortunate complications can always be obviated by a routine inspection of the fracture.

There are some questions that are of great interest when discussed in the light of recent revelations in surgical pathology, and which call for special study and observation in connection with the treatment of compound fractures; such are malignant disease, tenotomy, healing by Schede's method, amputation, the conversion of simple fractures into compound, and compound fractures involving the major joints.

The question of malignant disease following fracture is an exceedingly important one in surgical pathology. The late Dr. S. D. Gross pointed out the important fact that almost half of the cases of malignant bone disease can be traced to traumatism.

The author recently operated upon a child with an immense sarcoma upon the occiput. The child had sustained a heavy fall upon the back of the head six months previously, followed at once by the development of a large hæmatoma. The hæmatoma was not incised, and a linear

fracture existed beneath it. For some weeks after the injury there was nothing special excepting the presence of the hæmatoma, but the tumor then began to grow very rapidly, and in less than six months from the receipt of the injury the sarcoma was much larger than the child's head. The patient died some weeks after an incomplete operation for removal of the tumor. I have many beautiful specimens illustrating the fact that a fracture may be the starting-point of this variety of tumor.

The prognosis of sarcoma affecting bone as a result of fracture, while grave, is not necessarily fatal, provided the tumor is recognized before glandular swelling appears and the operation is performed early and includes the tissues far from the seat of disease and the bone itself.

Epithelioma also may develop indirectly as a result of a compound fracture, but this malignant growth has its origin from the soft tissues in connection with a sinus leading down to necrosed bone. If a sinus is not healed, it becomes lined with epithelium, and a discharge of ichorous pus through it from time to time sets up an irritation with a proliferation of epithelial cells, and epithelioma may in this way secondarily develop. While the epithelioma is not directly connected with the seat of fracture, as is the case in sarcoma, nevertheless, the disease may have its origin in conditions arising from sequestration in a compound fracture. The closure of sinuses in connection with necrosis following a fracture should always be aimed at by the surgeon.

Six years ago the author called attention to tenotomy in the treatment of compound fractures, and in a number of cases since then he has been impressed with the value of the operation in all oblique compound fractures, as well as in many simple fractures. Tenotomy relieves at once any contraction of the muscles, permits the fragments to be placed in accurate coaptation, and secures physiological rest to the fracture. It affords also great comfort to the patient, and is a valuable means of fixation during the first ten days. Tenotomy may be employed upon the tendo Achillis, upon the hamstring muscles, upon the tendons of the arm and forearm, and even upon the sterno-cleido-mastoid muscle in fractures of the clavicle. In several cases of compound fracture of the tibia where the line of fracture was parallel with the long axis of the bone, with considerable separation, a horseshoe tourniquet has been found to be a most valuable instrument in closing the long fissure. The instrument by pressure overcomes the lateral separation, just as tenotomy by relaxation overcomes the oblique displacement. The pad can be applied upon one side of the bone, and pressure be made by applying the other pad over a thick plaster bandage. The screw can be gradually tightened, and in a few days the bone can be approximated and the instrument discarded. This is a safer and more satisfactory instrument than the apparatus devised by Malgaigne. Muscular spasms can in many cases be overcome by position. Relaxation of the muscles will always relieve the spasm. The use of sulphonal, as well as of many other drugs has been suggested, but, as a rule, they do not relieve the condition.

Healing by Schede's method is effected by the intervention of blood-clots. It has usually been taught that blood-clots in wounds are obstacles to repair by primary intention, and that these clots act as foreign bodies.

Fluid blood and clots, if perfectly aseptic, are valuable adjuncts in the

repair of compound fractures. They are, however, most potent sources of evil if any infection reaches the clot through carelessness of the surgeon. It is a most valuable contribution to the treatment of compound fractures if the blood which escapes between the ends of the fragments can be in the future utilized as a means of hastening and perfecting union by primary intention. The reason why so important a principle in surgical pathology has been so long unknown is explained by the fact that blood-clots, until rigid asepsis was established, were recognized sources of septic infection. If all the surrounding parts in every compound fracture are made aseptic, clots and fluid blood can be utilized for the purpose of healing. Anything short of absolute surgical cleanliness will convert these clots and the blood into dangerous agents of infection.

Amputation.—Amputation of the limb in compound fracture was formerly resorted to with great frequency in hospital practice. Before the introduction of antiseptics pyæmia destroyed the life of almost every patient suffering from compound fracture who was brought to a large metropolitan hospital. The time is within my own recollection when, in Bellevue Hospital, amputation was immediately performed as a routine treatment to prevent blood-poisoning upon the admittance of a compound fracture; and this operation was considered by surgeons as offering to the patient the only chance of recovery. At the present time limbs are saved which would then have been sacrificed, and it is a rare event to witness an amputation in compound fracture. Extensive fracture of the bone with protrusion of the fragments through the soft structures would not now form an indication for amputation unless the soft structures were badly lacerated. Formerly the loss of a few inches of the bone called for primary amputation, but this no longer offers an indication, for the bones are brought together by silver wire, and, though the limb may be shorter than its fellow, the member is still retained, and elevation of the shoe compensates for any slight irregularity in the length of the limb.

The limits within which amputation in compound fracture may be resorted to are now exceedingly narrow and restricted, and this clinical fact is one of the most notable steps in the advance of modern surgery. Another important point in reference to amputation in compound fracture is the proper line of treatment to be pursued up to the time of the operation. It often happens that a patient is suffering too profoundly from shock to make it expedient to amputate. In these cases great benefit is to be derived from deferring the amputation even many days, until the condition is such as to justify the operation. Formerly this could not be practised without subjecting the patient to a greater risk from septic infection than would be incurred by an amputation during shock. If the wound is at once made aseptic and compresses are placed over the fracture to control the hemorrhage, and these compresses do not extend higher than the wound itself, the amputation can be deferred. It is important that these compresses be applied only over the wound, and that no tourniquet or any other form of compression be applied to the limb in the continuity of the artery above the injured part for any length of time, since if this is done there is danger of gangrene in the flaps after the amputation. In one case gangrene followed an amputa-

tion of the leg where a tourniquet had been placed over the femoral artery. This patient was brought to the hospital from a neighboring town with a tourniquet upon the femoral artery for the purpose of arresting hemorrhage in a compound fracture of the leg, and I call attention to the case in order to emphasize forcibly this point.

The conversion of simple fractures into compound or complicated fractures may happen, especially when the muscular spasm is great, or during the transportation of a patient suffering from a simple fracture; or there may be spontaneous conversion by means of the necrosis of a small fragment. An abscess subsequently forms and pus is set free, and the seat of fracture is exposed to the atmosphere. The author has observed, for example, a Pott's fracture—that is to say, a fracture of the fibula three inches above the tip of the external malleolus, with a laceration of the deltoid ligament—converted after several weeks into a typical compound and complicated fracture, owing to the necrosis of the distal fragment. Suppurative arthritis of the ankle-joint ensued, with caries of the astragalus. The ankle-joint was opened, the carious fragments removed, the joint freely irrigated, and an antiseptic dressing applied. The patient recovered in a few weeks with a useful joint. The possibility of nature transforming a simple fracture into a complicated one must not be overlooked. In such cases prompt surgical interference may arrest the progress of the disease and effect perfect restoration of a joint; otherwise this complication leads to irreparable damage, if not to loss of life.

The treatment of compound fractures involving major joints has been entirely revolutionized since the introduction of aseptic surgery. The unsatisfactory results in fracture-dislocations are due in a large measure to a want of rigid asepsis on the one hand, and a too extensive operative interference on the other. For example, the joint may not be rendered thoroughly aseptic at the beginning, and may be too extensively interfered with as regards operative procedures.

In the 171 compound fractures involving joints recorded in the 1000 cases referred to below the results as regards the usefulness of the joint have been in nearly all the cases perfect. To have a compound fracture-dislocation of the ankle-, knee-, elbow-, or shoulder-joint repaired with complete restoration of function is the aim of the surgeon. In one of the cases the astragalus extruded from the joint, and was reinserted, and perfect movement of the joint followed. These ideal results are to be obtained only by the exercise of great care. In all fracture-dislocations the joint should be immediately rendered absolutely aseptic by thorough irrigation. The drainage should be entirely across the joint, otherwise a pocket for the retention of inflammatory exudates is sure to form in the fold of the capsule. These products under certain conditions are sources of great danger. A careful study of cases of fracture-dislocation reveals the history of an abscess-formation upon the side of the joint opposite to the original wound several weeks after the injury. This complication may be obviated by free drainage. It is not sufficient to drain one side only, and that side through the original opening into the joint, but the tube must pass entirely through and across the joint. Physiological rest for many weeks must then be secured, and no passive motion employed for at least six weeks. Passive motion too early em-

ployed has often excited inflammation which has led to suppurative arthritis. Active motion must follow in its turn, but not for some time after the employment of passive motion and massage. A proper sequence in the employment of these different agencies is most important in order to reach an ideal result.

The complete histories of the one thousand cases of compound fractures have been carefully recorded. The general summary is as follows:

Skull	178
Nasal, malar, maxillæ, and patellæ	89
Arm	40
Forearm	41
Fingers and toes	97
Ilium, clavicle	2
Thigh	87
Leg	295
Fractures involving shoulder-, elbow-, or wrist-joints as a result of disease or accident	39
Fractures involving hip-, knee-, or ankle-joints as a result of disease or accident	85
Fractures involving carpal or metacarpal, tarsal or metatarsal joints as a result of disease or accident	47
	1000

Now, following the example of surgical writers who have carefully tabulated the results of treatment in compound fractures, the author has eliminated all those cases in which primary amputations were performed, because they do not concern the point at issue, and, according to the practice of writers, has rejected all those cases which died of hemorrhage, collapse, shock, etc. within forty-eight hours; in fact, most of such cases died within a few hours after injury. He has also left out cases of compound fractures of the hand and foot as too insignificant to be classed with compound fractures of the long bones or of the skull.

In the total of 1000 consecutive (and, of course, unselected) cases of compound fractures produced by traumatism or by operation, there were 101 deaths, 60 primary amputations, and 4 cases where the results were unknown on account of the removal of the patients from the hospital, at their own request, immediately after their admittance. In the 101 deaths, 82 died within forty-eight hours after the accident and during shock, and consequently these deaths should not be included in any figures to ascertain the percentage of mortality, because the patients died before any plan of treatment could be adopted having reference to the repair of the fracture or to the prevention of septic infection.

The remaining 19 deaths occurred from the following causes: One from tuberculous meningitis following some weeks after a resection of the hip-joint, so that this case died from other causes than septic infection; another from uræmia in chronic Bright's disease one week after wiring the patella. The wound was, however, healed and perfectly aseptic, so that this case died from other causes than septic infection. Another died one month after trephining, from exhaustion and inanition, with the wound perfectly healed by primary intention, and, as shown by the autopsy, with no evidences in the brain of the pathological changes of sepsis, so that death in this case cannot be attributed to septic infection. Two other cases died from irreparable damage to the brain, in one

of which the lock of a gun was driven through the skull into the brain, and in the other a fracture at the base was found at the autopsy in addition to the fracture of the parietal bone, so that death in neither of these two cases was due to pyæmia or septicæmia. Four other cases died from cerebral softening, which was situated at a distance from the original wound. One case died from diphtheria after the external wound of the compound fracture had healed. The wound was aseptic, and was never the seat of any disturbance, and, as the diphtheria affected the larynx and trachea, the cause of death was in no way connected with the fracture, although, of course, the time was too short to have the bone firmly united. One case of compound fracture of the skull died on the fifth day, but in this case the patient was suffering from a fracture of the spine which caused his death by myelitis. One case died within forty-eight hours after admittance from cerebral abscess connected with a punctured fracture of the skull, which had been operated upon two weeks previously by a surgeon in a neighboring town. During the patient's sojourn in the hospital he was trephined and seven ounces of pus were evacuated from the brain, but he died a few hours later. This case is excluded, on the ground that the patient's injury was not treated in the hospital, and that he did not enter the hospital until within forty-eight hours of his death. The death was clearly due to sepsis, but the circumstances were such as to relieve the hospital surgeon from all responsibility. One case died after forty-eight hours, but it was a case of primary amputation. The patient was run over by a locomotive; both feet were crushed, and the hanging toes were removed as soon as his condition would permit. One case similar to the last died from a crushed foot ninety hours after the accident. The patient was over sixty years of age, and never reacted from the shock. The remaining case of death was due to leptomeningitis, which occurred fifty-two hours after trephining, and was due to sepsis.

Finally, in order to arrive at the mortality in this list of one thousand compound fractures, there must be deducted from the original 1000 cases 60 primary amputations, because no treatment of the fracture itself was undertaken; 82 deaths from shock occurring within forty-eight hours, because no treatment was begun; 4 cases where the result is unknown, because the patients left the hospital of their own accord; 155 cases of compound fractures of the fingers and toes, because they are too insignificant; also 18 cases just mentioned in detail. There then remain 681 cases of compound fractures with *one death due to sepsis*. This gives a death-rate of about one-seventh of 1 per cent. The reduction of the death-rate from 48 per cent., which half a century ago was considered a brilliant achievement and a result which was thought worthy of publication, to that of one-seventh of 1 per cent. represents what surgery has done for the amelioration of human suffering and the preservation of life in this special field of surgery. To Pasteur and to Lister the profession are indebted for this great work—the former as the discoverer of the means, and the latter as the one who applied the discovery to surgery.

Complications.—*Complications during and after repair of fractures* forms a most interesting subject for observation and study. The complete usefulness of a limb is not fully restored as soon as the fracture has been repaired. During the process of repair, as well as after union

is complete, it is possible for many complications to arise that require special treatment.

Surgical emphysema is a condition that is often met with in the management of fractures. This consists of the entrance of atmospheric air into the meshes of the connective tissue, and is termed "surgical emphysema" to distinguish it from emphysema of the lung. The source of the infiltration of the air into the connective tissue may be from injury of the lung in fracture of the rib, in which case the emphysema has been observed to reach to the scrotum, and at times it may spread over the face, so that the patient is unrecognizable. The air may escape to such an extent as seriously to embarrass respiration. Another source of emphysema may be from the generation of gases as a result of putrefactive changes or of the growth of gas-producing bacilli in the tissues. There are only a few cases observed of emphysema in simple fractures; the majority of the cases have been complications in compound fractures. Or the gas may escape from a wound in the intestine, or even from the air-sinuses in the bones of the face and skull.

If the emphysema arises from injury to the lung, no interference is indicated unless the emphysema is so extensive as to produce dyspnœa, in which case free incisions can be made or the air allowed to escape through a trocar. The air is usually absorbed in a few weeks, and produces no harm, since it has been filtered in its passage through the lungs, and is therefore incapable of setting up inflammation. In case the condition arises from putrefactive changes, the application of the principles of antiseptic surgery is required; if from a wounded intestine, a laparotomy must be performed at once, the peritoneal cavity rendered aseptic, and the wound closed.

Œdema consists of the infiltration of serous fluid into the interstices of the areolar tissue, and, unless it is due to some organic disease of the liver, kidney, or heart, is the result of too tight bandaging or the sudden removal of the splint, or, finally, of obliteration of the large veins from thrombosis. If due to local causes, the œdema usually disappears after the removal of the cause, or, if to a loss of support of the vessels by the removal of the splint, the œdema rapidly subsides as soon as the function of the limb is restored. Placing the limb under a faucet and douching it alternately with hot and cold water will stimulate the circulation; and this treatment, aided by the action of the muscles when the patient begins to walk, will relieve the condition.

Delirium tremens and *traumatic delirium* are two complications that frequently occur. The differential diagnosis is often difficult to make, but tremor in the limbs and an alcoholic history, with absence of fever, point to the former as contrasted with the latter condition. In both forms of delirium the patient has delusions, mutters incoherently, is often violent and excitable, and has a dry, tremulous tongue accompanied by free diaphoresis.

The treatment consists in placing the fracture at once in a plaster-of-Paris splint and watching the patient carefully, even to the extent of employing a special attendant. If the delirium becomes too active, and it is impossible to restrain the patient, a strait-jacket must be employed. If the patient is robust and young, alcohol can be withheld, but if aged and feeble, it is necessary to continue stimulants with judgment.

The bromides, chloral, hyoscyamus, and in some cases morphine, are the remedies which have proved the most successful. In organic disease of the kidney morphine is apt to cause suppression of urine, and must be employed with caution. The diet must be nutritious and abundant, and the patient's strength maintained.

Pneumonia is a complication likely to arise during the repair of a fracture. It is especially likely to occur in alcoholic patients and in compound fractures, and forms a most serious complication. The treatment of the disease is conducted upon the same principles that govern the physician in a case of ordinary pneumonia.

Tetanus is fortunately a rare complication occurring during the repair of fracture. In a tabulation of over twelve thousand fractures there were 25 deaths from tetanus, or about 1 case in 500 fractures. In the 25 cases of tetanus taken from this large list the disease developed in only 3 simple fractures. The proportion of cases of tetanus in all kinds of fractures is only about 1 per cent. The greater number of cases of tetanus occurring in compound fractures is explained by the entrance of the bacilli of tetanus from external sources of infection, as dirt, air, and surrounding media. This percentage was derived from cases treated in pre-antiseptic days, so that with antiseptic principles applied to the dressing of a compound fracture tetanus ought not to appear as a complication. In the author's list of one thousand cases of compound fractures no case of tetanus appeared. The disease usually occurs in compound fractures, and especially those of the fingers and toes, in which over 50 per cent. of the cases of tetanus occurred. Compound fractures of the thigh furnished a large percentage of the cases. The cause of the disease is the presence of the bacillus of tetanus. The treatment consists of division of the main nerve-trunk or stretching it, or even amputation of the extremity. Calabar bean, morphine, chloral, the bromides, the inhalation of chloroform, and the Russian bath have been employed with varying degrees of success. For a full description of the treatment the reader is referred to the article on Tetanus. Strict antisepsis must be rigidly enforced in any case, since the disease is due to the presence of a specific germ.

Osteomyelitis is a form of suppuration in bone, and is caused by the presence of septic micrococci in the wound. It is therefore most likely to occur in compound fractures, although the disease in the form of acute abscess may occur after any traumatism of bone. The osteomyelitis sets up necrosis of bone, and the patient may die from septic infection before the sequestrum can be removed. Septic emboli may start from the thrombi, and metastatic abscesses develop. The treatment of this condition consists in freely exposing the seat of the abscess, and trephining the bone above it if necessary in order to reach the disease, with a view to destroying the micro-organisms with a solution of bichloride of mercury. The application of the principles of antiseptic surgery will destroy the disease, and if not amputation of the limb is indicated.

Fat-embolism was first fully described by Wagner and Zenker. Fat-embolism means the entrance of fluid fat from the medulla of the bone into the veins in the immediate vicinity of the fracture, and through these channels into the capillaries of the brain, spinal cord, lungs, kidneys, and other essential organs. The presence of fluid fat in

the blood was described in 1836 by Dr. R. W. Smith, but the clinical importance of this condition was not recognized until recently through the investigations of Bergmann, Czerny, and Scriba. Dejerine has experimentally produced fat-embolism in the lower animals by inserting laminaria tents into the medullary cavity of the bone. The symptoms of fat-embolism appear on from the third to the fifth day as a rule, and resemble those of secondary shock. They occur before the time at which venous thrombosis or pulmonary embolism would be expected to appear. Great dyspnœa, associated with the Cheyne-Stokes respiration, irregularity of the heart's action, with a sudden rise of temperature, together with twitching of the muscles, as well as paralysis of certain muscles, have been observed in these cases, and also fat-globules are found in the urine. There have been no metastatic abscesses discovered where an autopsy has been made. This group of symptoms must not be mistaken for shock following fracture nor for pulmonary embolism. Shock may be said to be present *three hours* after the fracture, fat-embolism *three days* after, and pulmonary embolism *three weeks* after. For convenience these complications have been arranged in the order in which they are most likely to occur, and by associating these conditions, which simulate each other, with the time at which they appear, no mistake in diagnosis is likely to arise.

The treatment of fat-embolism consists in the administration of ether in the form of some such preparation as Hoffman's anodyne, or even by hypodermic injection. In case of great dyspnœa venesection has been suggested, and also artificial respiration. The pulmonary œdema must be relieved by cardiac stimulants and by cupping. The fracture should be kept perfectly quiet, lest any movement of the fragments might cause further absorption of the fat by disintegrating the medulla. In cases where there is great comminution of bone and disintegration of the medulla amputation may be immediately indicated as a life-saving expedient.

Gangrene of the limb may occur either as a result of mechanical or traumatic causes or from septic infection. Gangrene arising from mechanical causes is due to the application of too tight a splint or bandage or to the improper and prolonged use of a tourniquet. The gangrene resulting from traumatic causes is due to a crushing or laceration of the soft structures near the fracture, or else to the rupture of the main vessels by the same agency which produced the fracture, or by the sharp fragments of bone, or, finally, to pressure from hemorrhage or from an unreduced fragment. The occurrence of gangrene often leads to suits for malpractice in the treatment of fractures. It is therefore important for the surgeon to define clearly the causes over which he has control, and those which are beyond his control, such as contusion, laceration of blood-vessels or nerves, pressure of a fragment of bone, or the obliteration of the lumen of the artery from thrombosis due to senile changes or calcification of the artery, and the presence of diabetes, with which gangrene is so often associated, especially after an injury.

The treatment must depend upon the cause, the extent, and the general infection of the patient. In small, localized areas of gangrene measures should be adopted to encourage the separation of the slough, while in gangrene with a line of demarcation forming amputation can

be resorted to when the healthy and dead tissues are clearly defined. In case of rapidly-spreading gangrene, with symptoms of serious septic intoxication, amputation high above the gangrene should be immediately performed.

Pyæmia and *septicæmia* are conditions which arise in the course of the repair of a fracture, and for a full description of these complications the reader is referred to the article devoted to a consideration of this subject.

Thrombosis is a complication that under rare circumstances occurs. When a vein has been wounded, a clot forms which closes the vessel. From this thrombosis an embolus has been known to originate and travel to the lung, where it has caused death by plugging up the pulmonary artery. This complication occurs, without any warning, about three weeks after the receipt of the fracture. The patient expires suddenly with great dyspnœa, cyanosis, feeble pulse, and angina pains. It occasionally happens that small emboli may become detached, and produce alarming symptoms which gradually disappear. In all cases where there has been obliteration of the veins, with formation of thrombi, it is dangerous to practise massage early or to disturb the seat of fracture, since an embolus might be torn away from the thrombus and set free in the circulation.

Hemorrhage to a certain extent occurs after every fracture, but the amount is usually so small that it requires no treatment. If, however, the quantity is large, there is danger of sloughing and gangrene, owing to pressure. The seat of the hemorrhage is between the integument and fascia, or it may be beneath the fascia. The source of the hemorrhage may be from the medulla of the bone, from the associated contusion and laceration of the soft structures, or even from a rupture of the main artery or vein of the limb. When the hemorrhage is from the medulla the blood escapes from the broken ends of the fragments, and after a few days undergoes absorption. When the hemorrhage is from the contusion of the soft parts the amount may be considerable. The blood may appear in the form of a fluid tumor or as a semi-solid mass due to coagulation. If the blood is fluid, an aspirating needle, rendered aseptic, can be introduced into the tumor and the blood withdrawn, and at the same time equable compression can be employed in order to obliterate the space or cavity which is formed by the sudden withdrawal of the blood. If the blood has coagulated, the clot may undergo a certain amount of absorption and contraction, or it may by pressure cause irritation, and by tension set up inflammatory reaction, quickly followed by suppuration. If the latter takes place, the abscess must be opened, the remnants of the clot removed, the cavity irrigated with a bichloride solution, and then dressed antiseptically. If the hemorrhage proceeds from a rupture of the main artery of the limb, a traumatic aneurism is formed. If the aneurism is small, the pulsation is feeble, and the circulation is good in the distal branches of the artery, slight digital pressure on the main artery above the aneurism will sometimes cure the aneurism. If an artery is wounded subcutaneously as a result of fracture, and the hemorrhage is not excessive, it often happens that in a healthy patient repair will take place without any operation. If, however, the aneurism is large, the pulsation strong,

the circulation below the injured vessel feeble or entirely shut off, and the patient in a dangerous condition from loss of blood, the operation of cutting down upon the vessel, turning out the clot, and ligaturing *both ends* should be immediately performed. If the femoral artery is wounded, or both tibials, this operation of ligating may be inadequate, and the condition may call for amputation. In primary hemorrhages *both ends* of the divided vessel should be sought for and ligated in the wound, while in secondary hemorrhage the vessel should be tied in its continuity, and above in healthy tissue.

Atrophy of the limb following fracture is a complication that is likely to occur, especially when there has been long-continued disuse of the limb, as in fracture of the patella. The atrophy is most marked in the muscles above rather than in those below the joint nearest to the fracture, and it is especially prone to appear in rheumatic diatheses and to involve the extensor muscles. The atrophy involves the connective tissue as well as the muscles, and the condition may be dependent upon an injury to the nerves in the limb, or possibly to a too-prolonged use of continuous compression. The atrophy is susceptible to treatment by gentle massage, hypodermic injection of strychnia, shampooing of the limb, and moderate exercise.

Paralysis of the muscles below the seat of fracture may occur as a complication during the repair of fracture, as a result either of associated injury to the nerves supplying the affected muscles or of an inclusion of the nerves in an exuberant callus during the process of repair. In the former case the paralysis is present simultaneously with the occurrence of the fracture, and if the nerve is a mixed one there will be loss of motion and sensation. The simple tests for motion and sensation should be made in examining every case of fracture, since a paralysis which is overlooked at the time of the examination of the fracture may be attributed subsequently to carelessness on the part of the surgeon. This knowledge will prevent any possible claim for damages. In the latter case, where the paralysis results from pressure of callus, the symptoms appear gradually and some time after the occurrence of the fracture.

In cases where the paralysis is due to pressure, electrical stimulation of the main nerve-trunk above the callus fails to excite the muscles to which the nerve is supplied.

The treatment consists in extricating, if possible, the nerve from the callus by means of a surgical operation, and the application of the constant current to the nerve until it has regained its function.

Ankylosis of joints occurs as a complication following fracture. The ankylosis may be either permanent or temporary. The permanent variety consists of an osseous ankylosis, and the condition is a result of a fracture directly into the joint, so that the fragments within the joint have become united. For the removal of this condition surgery can offer no relief unless an aseptic resection of the joint is performed, and this operation is limited to a few of the joints, like the shoulder, elbow, wrist, and ankle, with possibly a few others. The temporary ankylosis is the result of a concomitant injury which has set up an arthritis, or it may be due to the prolonged use of extension in the treatment of certain fractures, or it may be the result of hemorrhage into the joint

which has excited a synovitis and arthritis, with the formation of intra-articular bands of fibrous tissue. In Colles's fracture the fingers are often stiff from a thecal inflammation, and it is with great difficulty that this condition can be relieved.

The treatment consists in massage, shampooing, the use of hot fomentations of bran, the alternate douching with hot and cold water, and active movement.

Necrosis of bone occurs as a complication during the repair of fracture, and is due to the fact that the periosteum has been detached from the fragment or else from the shaft of the bone. In the former case the loose fragment should be removed at the time of the reduction and first dressing; in the latter case the superficial scale of bone undergoes necrosis, owing to its diminished vascular supply. Generally a sinus leads down to the exfoliated bone. This tract should be excised and the bone removed, as a long-continued sinus discharging ichorous pus is a condition favorable to the development of an epithelioma.

NON-UNION OF BONE occasionally occurs. In many cases the fragments may fail to unite at the usual time, and even fail after several attempts to induce repair; but eventually union can be accomplished. The author some years ago published a report of one thousand compound fractures, and in this list there was no case in which finally union was not obtained. Assuming that one compound fracture occurs to every ten simple fractures, there would be nearly ten thousand cases of fractured bones in which the author cannot recall a single case of permanent non-union. Where the fragments could be approximated they in a few cases failed to unite after several attempts in the way of operative interference, but finally a union was effected, although in several cases as many as seven or eight operations were performed. The femur and the humerus occasionally fail to unite, and, next to these, the bones of the leg, and lastly the bones of the forearm. That part of the bone which is away from the direction of the nutrient artery is most likely to give rise to non-union. In the sitting posture, if the elbow- and knee-joints are strongly flexed, the nutrient arteries take a direction downward, or in the upper extremity the nutrient arteries run *toward* the central joint, while in the lower extremities the nutrient artries run *away* from the central joint. From this anatomical law the upper part of the humerus would be the most frequent seat of ununited fracture; and in support of this statement out of 13 cases reported of ununited fractures of the humerus, 9 were in the upper extremity of the bone. In 8 ununited fractures of the forearm, 7 were in the lower part. In the same manner, applying this anatomical law to the lower extremity, it is found that the cases of non-union are found in a very large proportion of the cases in the lower part of the femur and in the upper part of the tibia. The intra-capsular fracture of the neck of the thigh-bone is an exception, but in this case the non-union is due to special causes, which will be considered in a discussion of this special fracture.

The *causes of non-union in bones* after fracture are constitutional and local. Among the *constitutional* causes, in which the reparative action is impaired or misdirected, may be mentioned old age and certain constitutional diseases, as fevers, syphilis, scurvy, malignant disease of bone, and rickets. Paralysis may also be a cause, as is illustrated by a case

of spinal injury with fracture of the humerus and leg of the same side, in which the arm united, but the leg failed to unite.

The puerperal state is another constitutional cause which has been mentioned by some writers, but the author has never found this condition to permanently cause a non-union in fractured bones, although in some cases the bones fail to unite until after parturition or until several operations have been performed.

Among the *local* causes of non-union may be mentioned the direction of the line of fracture, since oblique fractures are more frequently attended by failure of union than transverse or impacted. Among the other causes may be found separation of the fragments, the interposition

FIG. 44.

of foreign bodies between the ends of the broken bones, or suppuration, profuse hemorrhage, the continued use of wet dressings, and, finally, improper dressings, in which the splints are either too tight or too loose (Fig. 44).

The treatment of non-union of bone following fracture is to be considered from a constitutional as well as a local point of view. It is the union of the two methods that is sure speedily to bring about the desired object. In every case a careful inquiry should be made in regard to certain diatheses. The treatment of this unfortunate condition has for its object the correction of any constitutional dyscrasia. A syphilitic diathesis should be treated with the full administration of antisyphilitic remedies; a gouty or rheumatic tendency, by remedies suited to these special diseases; scurvy, rickets, scrofula, tuberculosis, and marasmus should be treated with tonics and a nutritious diet, with the aid of the best hygienic surroundings. The tonics best suited for those conditions in which the general health is impaired are iron and the phosphates.

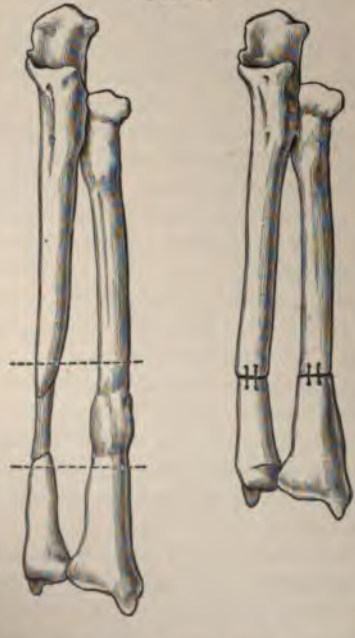
In conjunction with the general management the local treatment is to be pursued. The means employed must consist of the removal of any offending body between the fragments and the excitation of a certain amount of inflammation around the ends of the fragments. The local treatment must further consist in the application of an immovable splint specially adapted to the exigencies of the case.

The operations which have been devised with a view to effecting union in ununited fracture are multifarious. They all have one common object—viz. the excitation of inflammation; but many of the old operations are at the present time abandoned as a result of the introduction of antiseptic surgery. The use of the seton, the injection of irritating fluids, the cauterization of the fragments, the application of blisters and of caustic alkalies to the skin over the site of the ununited fracture, the

introduction of electrical currents, the violent percussion with the mallet, —are among the various operations which are practically discarded as unsuitable, and in their places modern surgery has instituted a number of aseptic operations.

Before any other operation is attempted it is good surgery to try and perforate the bones, which is best accomplished by a Brainard drill. This operation is simple, is attended with no special danger, and in the majority of cases will bring about firm union. This method is especially indicated in cases where the patient's health is impaired, or the patient is aged, or where any lesion of important organs exists, such as would render a more serious operation a source of great danger. This operation can be accomplished without the administration of ether, and with but little pain, by the use of the freezing atomizer and by the hypodermic injection of cocaine through the anæsthetized skin: a small incision is made, and the drill is thrust into the bone. The drill penetrates the fragments in twenty or thirty places from the same opening in the skin. In these cases the ends of the fragments are usually devoid of periosteum, and the intervening tissue forming a false joint is partially insensitive; hence the pain is not unbearable. The soft parts around the seat of fracture should be thoroughly cleansed before drilling the bones, and the small puncture in the skin made aseptic before being hermetically closed. Closure of the wound is best effected by iodoform powder freely sprinkled over the wound, and over the powder should be painted styptic collodion with a thin film of borated cotton, and in this way a firm scab is formed, which closes the wound and converts the small compound fracture thus made into a simple one. The drilling causes considerable inflammation, and the determination of blood to the part carries with it the materials for osseous repair. This simple operation is worthy a trial in ununited fractures, even though subsequently a more serious operation under ether might become necessary.

FIG. 45.

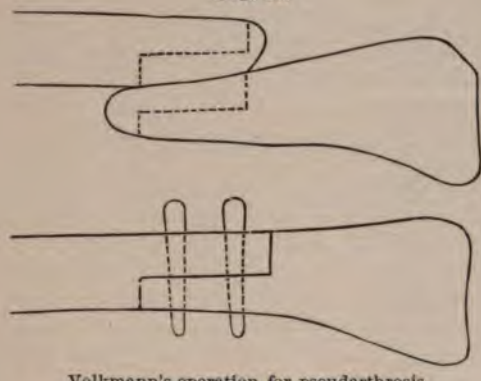


The operations for non-union in fractures where drilling has failed consist of cutting down upon the site of the fracture and exposing the false joint. Great care should be exercised to avoid wounding any of the important vessels and nerves. The intervening fibrous tissue should now be cut away, the two ends of the bone brought out, and a small piece of each end sawed off, so as to secure a fresh osseous surface. The manner of further procedure must necessarily depend upon whether there are two parallel bones or there is only one single bone in the extremity. If there are two bones, no union can be effected unless a corresponding section of

the opposite bone is removed, in order to have the broken ends brought in apposition (Fig. 45).

There are several methods of fixation of the exposed fragments. In some cases the ends can be sutured by silver wire, and little shortening

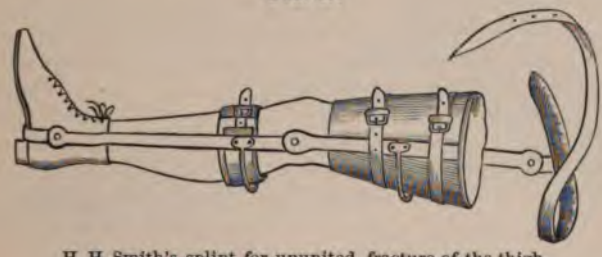
FIG. 46.



Volkmann's operation for pseudarthrosis.

is likely to follow. In other cases this method is inapplicable, since the ends are often too pointed to afford a sufficient breadth of surface

FIG. 47.



H. H. Smith's splint for ununited fracture of the thigh.

for union. Under these circumstances the periosteum should be preserved as far as possible, and a resection be made in each fragment, as

FIG. 48.

H. H. Smith's splint for ununited fracture of the leg.

shown in Fig. 46. The fragments can be fastened together by ivory pegs or by steel nails, or even sutured by strong silver wire.

Palliative measures are sometimes indicated where an operation for

any reason seems inadvisable. The accompanying cuts illustrate the principle upon which such treatment is based (Figs. 47 and 48).

In extreme cases, where the limb is useless, and suppuration is present to such an extent as to endanger life, amputation may be called for. Such treatment may be indicated where an operation to effect union has failed and suppuration and necrosis have followed.

It occasionally happens that no operation for pseudarthrosis is permissible, in which case a splint should be used, so that the patient can have a greater sense of security.

Special Fractures.

Fracture of the phalanges occurs as a result of direct violence, such as the passage of a wagon-wheel over the toes or by the fall of a heavy weight directly upon the part. Fractures of the toes may also be caused by the patient striking the foot against a chair or sofa while walking barefooted in the dark. If the fracture is compound, the wound can be dressed aseptically and a small splint applied, and the entire foot enveloped in a plaster-of-Paris bandage. The soft parts are very vascular, and the repair is very rapid and satisfactory. The danger from tetanus in compound fractures of the toes must not be overlooked. In the simple fracture of the phalanges a pasteboard splint should be applied wet and moulded to the toe, and the foot placed in a plaster-of-Paris bandage.

Fractures of the metatarsal bones occur in much the same way as those of the phalanges, only the degree of injury inflicted is greater. The same general rules will suffice in the management of fracture of these bones.

Fracture of the tarsal bones occurs from direct violence, and is usually associated with great destruction of the soft tissues. The skin is very apt to slough, and much care must be exercised in order to preserve the integrity of the tissues. Fractures of the scaphoid, cuneiform, and cuboid bones do not require any special consideration beyond that exercised in the general management of fractures of the metatarsal bones of the phalanges.

Fracture of the calcaneum usually is the result of a fall from a great height where the patient strikes upon the heel. This fracture has occurred a number of times in workmen on elevated railroads. The men in endeavoring to avoid a passing train have held themselves suspended in the air from the iron structure, and, not having strength enough to hold on until the train had passed, have dropped to the ground, and, striking upon the hard pavement, have broken the calcaneum of each foot. The fracture may also be produced by a wheel of a carriage or cart passing over the foot laterally while the patient is lying on his side upon the ground (Fig. 49). Fractures of the calcaneum may occur from muscular action, as where the tendo Achillis is suddenly contracted and tears the insertion of the muscle from its attachment. The detached tendon often carries with it a thin shell of bone from the posterior part of the os calcis.

The signs and symptoms of fracture of the calcaneum are such as to render the diagnosis clear. Crepitus, pain, swelling, and ecchymosis

are present. The heel itself is often contused, and is discolored from the bruise caused by falling upon the integument over the heel. The arch of the foot is often destroyed. The displacement varies in degree according to the situation of the fracture; thus, if the break traverses

FIG. 49.

Fracture of os calcis.

the part of the calcaneum in front of the attachments of the lateral ligament, there is usually but slight deformity, since the strong calcaneo-astragaloid ligaments holds the fragments *in sitû*. On the other hand, if the fracture is behind the insertion of the lateral ligaments, the tendo Achillis draws the posterior fragment well up, so as to cause a marked and characteristic displacement. The dense fibrous tissue surrounding the bone also helps to prevent much displacement.

The **treatment** of fracture of the calcaneum varies somewhat according to the seat of fracture. If the bone is broken in front of the internal lateral ligaments, the dense fibrous tissue about the bone and the sole of the foot prevents any marked displacement. The foot should be placed in the slightly extended position and a plaster-of-Paris bandage at once applied. If the bone, on the other hand, is broken behind the insertion of the lateral ligament, the displacement is well marked, and it becomes necessary to place the leg upon a double-inclined plane in order to relax the tendo Achillis, which causes the displacement. In

the treatment of this fracture division of the tendo Achillis will at once cause the deformity to disappear and the fragment to assume its natural position. The physiological rest thus secured will result in rapid repair of the fracture. It occasionally happens that neither the use of the double-inclined plane nor tenotomy will result in a coaptation and retention of the fragments. Under these circumstances the fragments can be wired by an aseptic operation, or an ivory peg can be driven into the fragment and thus fasten it firmly to the bone. If the fracture is compound and the fragments are loose, it is best to remove them, since necrosis of the small detached fragment is very likely to follow.

FRACTURE OF THE ASTRAGALUS occurs usually at the neck, since this is the weakest part of the bone. Fractures, however, are found through other parts of the bone, and also associated with fractures of the other tarsal bones, and even of the tibia and fibula. Fracture of the astragalus is produced in the same manner as that of the os calcis, excepting that it is never caused by muscular action, since there are no muscles attached to the bone. The bone is sometimes crushed between the tibia and the os calcis, and the fracture may also be accompanied by a fracture of the fibula or the os calcis, or even with a dislocation of the ankle-joint. Generally the ordinary signs of fracture are present, such as crepitus, pain, tenderness, and inability to bear pressure on the bone. The displacement is slight, as there is no muscle to cause traction on the fragment. The joint is often inflamed and the synovial fluid is abundantly secreted, so as to destroy the landmarks of the joint.

The treatment of this fracture is often fraught with difficulty, since it is attended with more or less synovitis. This complication is best treated by fixation of the joint in a fracture-box or some other temporary apparatus, and employing an evaporating lotion for a few days until the swelling has in a measure subsided. If the fragment projects under the skin, it is very apt to cause sloughing of the soft parts. If possible, the fragment should be pushed back in its place, even if it requires the employment of anæsthesia, for which nitrous oxide is the best form to use, since it is safe and lasts a sufficient length of time to make the adjustment. If the projecting fragment will not resume its proper position, division of the tendo Achillis will enable the surgeon to reduce the displaced fragment. The danger is very great that the fragment in fracture of the astragalus may become necrosed, and necrosis be followed by suppuration in the joint. This of necessity prepares the way for a secondary resection of the joint.

After the swelling has subsided the leg can be placed in lateral splints with rectangular foot-pieces, and thus maintained until the fracture unites. A plaster-of-Paris bandage or felt or leather splints can be used with cotton. The foot should be placed at a right angle to the leg, and there should be no inversion or eversion of the sole. If the fracture of the astragalus is compound, the fragment not only should be at once removed, but the wound and the joint irrigated with a weak antiseptic solution. It is important to introduce the drainage-tube entirely through and across the joint, since its employment with only one outlet is sure to be followed by serious after-effects. The anatomical arrangement of the joint is such that ordinary drainage is insufficient to meet the requirements of the case, and special emphasis is placed upon

free and complete bilateral drainage secured by a tube passing straight across from one malleolus to the other and placed in the most dependent portion of the joint. Great care should be exercised not to begin passive motion for at least three weeks, and active motion not sooner than five weeks. There is no doubt that the bad results after this fracture are due to incomplete drainage, to imperfect antisepsis, to improper splints, to the adoption of too early passive motion, and, finally, to the employment of active motion before the proper time has arrived.

The question of incision into the joint in a case of simple fracture of the astragalus, with a view to removing the fragment, is one about which no unanimity of opinion exists. Some surgeons prefer to wait and let Nature make the expulsion of the fragment, and not to interfere until suppuration ensues, while others believe that with the aid of antiseptic surgery a bold operation should be essayed. No general law can be laid down, and each case must be treated on its individual merits.

FRACTURES OF THE LEG may be classified into four groups: Fractures of the tibia and fibula, of the tibia, of the fibula, and epiphyseal separations.

Fractures of the leg form about 16 per cent. of all fractures. They are rare in infancy and during childhood, but between the ages of thirty and sixty the greatest number of fractures of the leg are found. Fractures of the leg are usually the result of direct, although they may be caused by indirect, violence, or even by muscular action. As a rule, the direction of the fracture in the lower part is oblique, while in the upper extremity of the limb the fractures are transverse.

At the outset too much stress cannot be placed upon the importance of so *lifting the broken leg* as to ensure absolute certainty against the conversion of a simple into a compound fracture. The patient should first be instructed to relax the muscles of his broken leg, and on no account, no matter how severe the pain is, to contract his muscles so as to resist the assistant whose duty it is to raise the limb. Having fully explained the importance of this to the patient, the assistant should grasp the foot at the juncture of the phalanges with the metatarsal bones, and make gradual extension in the long axis of the limb before attempting to raise it. As soon as the fracture is reduced he should lift the leg slowly from the bed. In this manner no accident can follow, and the pain consequent upon this necessary manipulation is very slight.

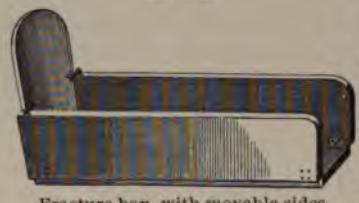
Fractures of the tibia and fibula occur by direct violence in the great majority of cases. They may, however, result from indirect violence or even by muscular action. They are produced by heavy weights falling upon the limb, by the kick of a horse, or by the passage of a car-wheel or heavy truck over the leg. When both of the bones of the leg are broken by indirect violence, the tibia is fractured lower than the fibula. This is probably due to the fact that the tibia is broken first, and the fibula then gives way upon a higher level.

The **signs and symptoms** of fracture of the tibia and fibula need no special description, since they are most marked in this special fracture. The irregularity of the line of the tibia is often a most important diagnostic sign. The displacement in fracture of both bones of the leg needs special consideration. The lower fragment, with the foot, is drawn upward and backward behind the upper fragment by the action of the

gastrocnemius, while the upper fragment projects just under the skin. There are likewise abduction of the foot and rotation of the leg outward, caused by the weight of the foot and of the lower fragment, owing to the loss of support.

The **treatment** of a simple fracture of both bones of the leg consists in the application of a suitable retentive apparatus. If there is much tension and swelling on account of inflammatory exudation, with hemorrhage and blebs or phlyctenæ, the limb should be placed in a fracture-box (Fig. 50), so that it is surrounded by oakum or bran. In a few days the swelling subsides, provided the limb has been kept quiet in the fracture-box. The phlyctenæ will disappear after they have been simply punctured with an aseptic needle and a small piece of iodoform gauze placed over the collapsed vesicle. If, on the other hand, there is no marked swelling, and no blebs upon which the pressure of a splint would cause sloughing exist, the limb can be immediately placed in a permanent dressing. It is axiomatic in fractures that the sooner a broken bone is placed in a permanent splint or bandage the better it is for many reasons. The early dressing of a fracture often prevents the swelling so frequently found where there has been delay in the application of a permanent and early splint or bandage. As to the selection of a special dressing for fractures of both bones of the leg, the opinions of surgeons are at variance. The writer has no hesitancy in recommending, with the exception mentioned, the immediate use of plaster of Paris in fractures of both bones of the leg. The great objection raised to immediate application of the plaster-of-Paris bandage is the danger of gangrene from pressure due to swelling. The writer has seen this unfortunate accident occur on several occasions in the hands of well-known surgeons; but it is certain that the gangrene was not due to the use of the plaster-of-Paris bandage *per se*, but to the improper and careless use of it. The writer has also seen a case of fracture of both bones of the leg in which plaster of Paris was immediately applied, and the entire limb became one mass of sloughing material concealed under the bandage, while the septicæmia resulting from this condition gave rise to the incorrect diagnosis of typhoid fever, from which supposed cause the patient died, but the incidental removal of the plaster bandage at the dead-house revealed the true cause of the septicæmia.

FIG. 50.



Fracture-box, with movable sides.

The manner of applying a plaster-of-Paris bandage (Fig. 51) is fully described elsewhere, but the special points in connection with the management of this particular fracture are first the use of a thick layer of absorbent cotton which will yield to any swelling, and thus prevent the danger of gangrene; and, second, the use of strips of perforated tin or zinc placed over the limb to give uniform support, and thus to obviate the necessity for a heavy bandage. These strips should be fitted to the sound limb, and then placed laterally in front, and along the posterior part of the broken leg, and bent around the heel so as to prevent any backward displacement of the limb during the repair. Great importance is to be attached to this posterior splint. As a matter of precaution

the toes should be examined after six hours to see if they are numb or if there are any signs of obstructed circulation, in which case the splint should be immediately cut off and a new one applied. At the expiration of eight days, if everything has proceeded favorably, a new splint should be applied. In another week the bandage should be removed to

FIG. 51.

Leg encased in plaster-of-Paris bandage.

inspect the fracture, since occasionally the fragments become disturbed under the bandage, and at this time they can be readjusted when later it would be impossible.

If the surgeon prefers a splint instead of the plaster-of-Paris bandage, the classical double-inclined plane of McIntyre is one in common use. Where there is much deformity and the fracture is not easily retained in apposition, this splint is useful, since it relaxes the muscles of the calf by flexion of the knee. In some cases of oblique fracture this splint is not well adapted to meet the emergencies of the case, as it does not overcome the tendency to rotation, and also because in flexion of the knee the quadriceps extensor muscle of the thigh has a tendency by its contraction to tilt forward the lower end of the upper fragment.

Halsted's sliding splint is most excellent when there is any tendency for the upper fragment to protrude. The writer has employed in certain cases the ordinary fracture-box with the addition of a weight and pulley to the lower fragment. After the leg has been placed in the fracture-box, which is filled with bran or oakum, with the movable sides turned down, a pad is placed under the tendo Achillis, and the sides are now closed up, leaving the vertical foot-piece flat. In cases where there are great swelling and a tendency for the upper fragment to protrude through the skin this dressing is found most useful.

Nathan R. Smith's anterior splint (Fig. 52) is recommended in fractures of both bones of the leg, as well as in fractures of the thigh.

The Bavarian splint is excellent if the fragments can be kept in apposition without artificial extension or muscular relaxation. In this same category may be mentioned the silicate-of-soda bandage, the lateral splints of leather or gutta-percha, and the heavy pasteboard side-splints. In the use of any of these side-splints care must be exercised to avoid the tendency of the backward displacement of the lower fragment with the foot.

The writer cannot too highly recommend division of the tendo Achillis in fractures of both bones of the leg when any tendency to muscular spasm or to marked deformity, or any premonitions of delirium tremens, exist.

Whatever dressing is employed, the surgeon must bear in mind the fact that the inner side of the ball of the great toe must be brought in

FIG. 52.

Nathan R. Smith's anterior splint.

line with the inner edge of the patella, and the foot maintained at a right angle to the long axis of the limb.

In fractures of the upper part of the leg the knee-joint may be involved, and then hæmarthrosis results, which may lead to serious joint disease. If the fracture is compound or complicated, the knee must be thoroughly irrigated and drainage-tubes inserted into the sides of the joint, since the open wound is often unsuitable to utilize for purposes of drainage. This is a serious operation, and must be performed in conformity to the rules laid down in connection with compound dislocations of the knee-joint.

FRACTURE OF THE TIBIA is of more frequent occurrence than fracture of the fibula, because the bone is less protected by muscles and receives the principal weight in falling. The fracture may occur at any point in the shaft, but the junction of the middle with the lower third is the more frequent seat, since this portion is anatomically the weakest part, owing to the fact that the diameter of the bone is less at this place than at any other part of the shaft. In this part the peculiar anatomical arrangement of the bony columns is such as to favor fracture upon the receipt of indirect violence. The bone is fractured at this place often by torsion.

Fractures of the tibia occurring in the lower part of the bone are usually oblique from above, downward and inward, while those in the upper part are transverse. The fractures in the lower part may be from direct, but usually they are from indirect, violence, while those in the upper part are generally produced by direct violence.

Fractures of the tibia may occur at the lower end, through the shaft, or at the upper end.

A fracture occurring at the lower end of the tibia usually involves the

internal malleolus. There is very little displacement, because the internal lateral or deltoid ligament, which is attached as well to the borders as at the apex of the malleolus, prevents the fragment from becoming detached. This injury often results in a permanent ankylosis of the ankle-joint (Fig. 53).

FIG. 53.

Fracture of the internal malleolus.

The **signs and symptoms** are so apparent that they need no special description.

The **treatment** consists in placing the detached fragment in its proper position and retaining it by the use of compresses placed between the malleolus and the inner side of the splint. It is highly important to have the fragment accurately adjusted, since any union in an abnormal position will result in too great lateral motion to the astragalus, and thus render the patient unable to walk with any sense of security. If the fragment cannot be placed and retained in its proper position by the ordinary measures, the operation of cutting down upon the fragment and wiring it, or of fixing it by the use of an ivory peg, would be in the hands of an antiseptic surgeon a just procedure. If the union is fibrous, it is apt to interfere with the free movement of the ankle-joint.

Fractures of the shaft of the tibia are not attended with much displacement, since the fibula acts as a side splint to keep the parts in apposition. In some cases the only **signs** that are present are fixed pain, localized tenderness on pressure, ecchymosis, a tendency to backward displacement, a slight irregularity upon passing the finger down the tibia, as well as an irregularity upon the surface of the bone. If the fracture happens to be in the lower third of the tibia, crepitus may be felt by grasping the foot firmly and rotating it.

The **treatment** consists in the application of side-splints of leather, pasteboard, or gutta-percha, or in the use of a plaster-of-Paris bandage applied in the manner already described.

Fracture of the upper end of the tibia is usually transverse and the result of direct violence in consequence of which the soft parts are more or less bruised and contused. There is usually but little displacement, since the transverse direction of the fracture prevents any marked deformity; if, however, the fracture is oblique, then the displacement is prominent. In this fracture by direct violence, where the bone is broken transversely, occasionally a T-fracture is found, and the line of fracture extends vertically into the knee-joint. In this case a considerable degree of deformity is present, since the knee-joint becomes at once the seat of acute synovitis, produced by the presence of blood within the capsule and also by the direct effects of the traumatism. If the fracture is oblique, the leg is deflected to one side, opposite to the direction of the line of fracture.

The **treatment** of this injury, situated in the upper part of the tibia, consists not only in the management of the fracture itself, but also in attention to the joint complication. It must embrace, therefore, a plan to reduce the inflammatory joint affection, as well as a retentive apparatus for the fracture. If the displacement is considerable, the deformity can be best overcome by the use of McIntyre's (Fig. 54) double-inclined plane, which by relaxing the hamstring muscles prevents any move-

ment in the long lower fragment, and makes this fragment conform to the upper or short fragment. The action of the quadriceps extensor is to tilt the upper fragment forward in case too great flexion of the knee is allowed. If but slight deformity exists, the fracture can be completely reduced and a plaster-of-Paris bandage employed, with a com-

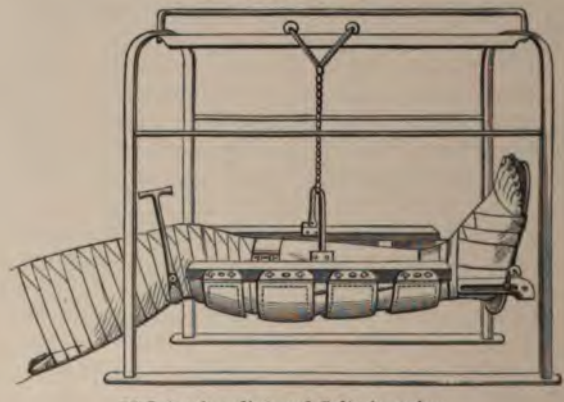
FIG. 54.

McIntyre's splint, modified by Liston.

press over the upper fragment. In some cases, where the muscles of the calf make traction on the lower fragment, tenotomy of the tendo Achillis will often overcome any tendency of the upper margin of the lower fragment to override the lower margin of the upper fragment. After three weeks gentle passive motion should be employed in order to prevent adhesions in the knee-joint.

At the beginning of the treatment it may be necessary to use cold evaporating lotions, the ice-bag, or Leiter's coil to reduce the local

FIG. 55.



McIntyre's splint and Salter's swing.

inflammatory condition of the joint. In all fractures of the leg in which the plaster-of-Paris bandage is employed it will be found that a suspension apparatus, such as Salter's swing (Fig. 55), will enable the patient to keep the fragments more quiet than when the leg rests entirely upon the mattress.

EPIPHYSEAL SEPARATIONS (Fig. 56) occur in young people under twenty years of age, and since they are produced in the same way as fractures, and present the same symptoms, and finally demand the same treatment, there is little to say in connection with them beyond what has already been said in relation to simple fractures of the bone in these localities. If the epiphysis is separated in a child, the growth of the bone is very much affected, so that when the patient has attained his full size the injured leg is much shorter than the opposite one. This shortening must be relieved by the use of a cork sole applied to the shoe.

FIG. 56.

Separation of the lower epiphysis of the femur (Bryant).

The **treatment** should be the same as for a fracture of the bone occurring either at the upper or the lower part of the shaft.

FRACTURE OF THE FIBULA may occur at any point, but there is only one special fracture that deserves separate consideration. This is known as "Pott's fracture," and consists of a fracture of the fibula about three inches above the external malleolus, with a laceration of the internal lateral or deltoid ligament, and in some cases a slight chipping off of the tip of the internal malleolus at or near the insertion of the ligament. This fracture is produced by a fall upon the foot, and the foot is twisted (Figs. 57, 58) outward, and occasionally there is a slight dislocation of the ankle-joint, caused by the astragalus rotating upon the under surface of the tibia. In some cases, besides the lesions just mentioned, the foot may be dislocated backward, since the lateral supports have been destroyed.

FIG. 57. FIG. 58.

Displacement in Pott's fracture.

The **treatment** of fracture of the fibula, with the exception of Pott's fracture, is extremely simple, since the tibia itself acts as a splint, and any ordinary dressing, such as leather, pasteboard, gutta-percha, or side-splints, will answer every purpose. In Pott's fracture there are only two dressings which are worthy of special consideration: the first being a plaster-of-Paris bandage, applied while the foot is held in marked inversion, with the addition of a strong posterior splint of perforated zinc, which is moulded first to the sound leg and then applied to the broken limb, in order to prevent the backward displacement, a deformity so apt to follow during the repair of this fracture. The other dressing is that known as Dupuytren's (Fig. 59), which consists of a board about four inches in width and of sufficient length to extend from the popliteal space to three inches below the foot. On the fractured leg a pad is placed which reaches from the popliteal space to the internal malleolus, with a thickness of one inch at the upper end and three inches at the lower end, where it extends to the tip of the internal malleolus. The leg, with the pad applied, is now laid laterally upon the splint, which is maintained by means of a few turns of a

roller bandage above and below. The application of the lower banda causes adduction of the foot, which relaxes the internal lateral ligame and brings the fragments in correct apposition. The limb is plac upon the side with the splint in contact with the bed.

FIG. 59.

Dupuytren's splint.

FRACTURE OF THE PATELLA demands careful consideration on account of its close proximity to the knee-joint, and also in consequence of the imperfect way in which the fragments usually unite. Fracture of this bone occurs in about 2 per cent. of all fractures, and it is found more frequently in the male than in the female—in the proportion of about 5 to 1. The period of most frequent occurrence is between the ages of thirty and fifty. If the fracture occurs in extreme old age, it is very likely to be found in the female.

Fracture of the patella is caused by muscular action or by direct violence. The direction of the fracture may be transverse, vertical, oblique, or even stellate. In the fracture produced by sudden and violent muscular contraction the transverse variety usually occurs. When the fracture is caused by direct violence the direction may be vertical, oblique, or stellate, or the fracture may be comminuted. The fracture by muscular action occurs when the knee is in the position of semi-flexion. When the joint is in this position the middle portion of the under surface touches the anterior surface of the condyle. A sudden and forcible contraction of the quadriceps extensor muscle, which acts at nearly a right angle to the vertical surface of the patella, causes it to snap, just as a stick is broken across the front of the knee. A fracture caused by muscular action is complete, and has also associated with it a tearing of the aponeurotic and fibrous coverings of the bone, as well as a laceration of the synovial membrane of the joint and a rupture of the prepatellar bursa. In consequence of the peculiar nature of this injury the joint is soon filled with blood, and the synovial secretion becomes abundant as a result of the irritating pressure of the blood-clots.

In fracture of the patella the knee-joint is always opened, unless the extreme lower end of the patella is broken, in which case it is possible for the fracture to exist without the joint involvement. Both patellæ may be fractured by muscular action. The writer has seen this in a case of an insane patient who suddenly attempted to spring out of a window. This accident has also been reported as the result of sudden extension of both limbs during the performance of lithotomy without an anæs thetic. The fracture of both patellæ has also been observed in a patien who attempted to save himself from falling backward on account of misstep.

Fracture of the patella caused by direct violence is the result o sudden force applied directly to the bone, such as a kick from a hor

a blow upon the anterior surface of the bone, or a fall directly upon the front of the knee-joint. In this fracture there is more injury to the soft parts about the joint, although usually the separation of the fragments is not so great, on account of the absence of muscular contraction. This fracture produced by direct violence is often compound, and also, in some cases, comminuted (Fig. 60).

FIG. 60.

Compound fracture of patella.

The **signs** of fracture of the patella vary somewhat according to the manner in which the injury occurred. The history of a fall during which the patient felt a sudden snap, or of a blow upon the knee-joint with some instrument, or of a kick by an animal, together with sudden loss of power in the limb, lengthening of the patella with a well-marked sulcus, with ecchymosis and swelling rapidly appearing, with a loss of the general contour of the joint,—are characteristic indications of fracture of the patella. The amount of separation between the fragments depends upon the degree of muscular contraction at the time of the accident, together with the amount of synovial secretion and the extent to which the lateral attachments of the patella are lacerated, and, to a certain extent, upon the contraction of the ligamentum patellæ. A patient has been known to walk after fracture of the patella, but this is a most unusual event. Crepitus is generally absent in this fracture, on account of the separation of, and the intervention of blood-clots and fibrous tissue between, the fragments.

A certain amount of displacement is sometimes found after the fracture has been repaired; for example, the fragments may be displaced to the side or in front. The lateral displacement is caused by the ligamentous or fibrous union stretching unequally, while the anterior displacement is due to the pressure of pads placed above and below the fragments, which causes them to tilt forward. The fragments may be pushed up by the underlying fluid, so that their anterior surfaces are not on the same plane.

The usual mode of union, to which, of course, there are exceptions, is not osseous, unless the fracture has been treated by opening the joint and suturing the fragments with silver wire. The question as to whether bony union ever takes place by the older method of treatment is settled without any doubt. A specimen in support of this statement is found in the Wood Museum, where the union is by bone (Fig. 61), the patient having been treated by Dr. Charles Phelps. The medium of union where the fracture has been subjected to the ordinary methods of treatment is fibrous tissue. Occasionally no direct union occurs, and the fragments are simply held in contact by the thickened fibrous capsule of the joint and the surrounding lateral tissues outside of the joint (Fig. 62). The reason why a transverse fracture of the patella seldom unites by bone is that at the time of the accident the fibrous tissue or the

capsule of the anterior surface of the patella falls down between the fra ments, and thus acts as a foreign body and prevents the coaptation of t bony surfaces, and consequently union by bone is rendered impossible.

The treatment of fracture of the patella consists in the applicati

FIG. 61.

Osseous union after a fracture of patella.

FIG. 62.

Ligamentous union after fracture of the patella.

of a suitable apparatus designed to bring into apposition the fragments. Some special management of the joint-inflammation before applying any permanent dressing is necessary. There have been published innumerable devices to meet the difficulties surrounding the treatment of this fracture. Concentric pressure causes a deficiency in the blood-supply; the small size of the fragments often causes them to tilt upward, and the bulging of the condyles with the leg extended prevents close apposition of the fragments; the synovitis and hæmarthrosis retard the union by separating the broken surfaces; and many other causes are in operation to prevent the osseous repair of this fracture.

Before any method is resorted to with a view to bringing the fragments into apposition the surgeon must endeavor to control and modify the joint-inflammation. The ice-bag is used with signal benefit during the first few days, after which lead-and-opium wash can be applied. Cold irrigation is sometimes employed instead of the ice-bag, and in some cases, where there is a good deal of superficial ecchymosis, a warm fomentation is applied. As soon as the heat has subsided gentle uniform compression with sponges can be employed around the joint, with a view to promoting absorption of the fluid in the joint. Blisters have been suggested, but their use is attended by so much inflammation of the skin as to prevent the application of any apparatus. After the expiration of a week the joint-complication should be sufficiently controlled to allow the application of some permanent dressing. The limb can be so placed that position alone affords an excellent method of treatment. Some surgeons simply place the limb on a splint and elevate the heel, so that the foot is from two to three feet above the foot of the bed; and in this way the rectus, crureus, and vasti are relaxed, so that there is no traction upon the upper fragment. With a view of still further relaxing the muscles the patient can be propped up on a bed-rest. If now the entire limb is bandaged and then the limb is bandaged to the splint, the

essential condition of the treatment is fulfilled. Without doubt this method has met with excellent success, but in the event of failure to secure a satisfactory result a surgeon might be exposed to criticism on the part of the patient, which might be an opening wedge for a lawsuit for damages.

Another plan has been suggested, which is likewise liable to result in an unsatisfactory manner, and that is immediate aspiration of the knee-joint and tenotomy of the quadriceps extensor muscle. This plan is too bold to recommend, since in some cases it has proved most disastrous by provoking a suppurative arthritis.

Still another plan has been suggested by Schede, of aspirating the joint, and then injecting into it a 3 per cent. solution of carbolic acid until the fluid withdrawn is perfectly clear, and at once applying a plaster-of-Paris bandage. This operation has been attended in some cases by suppuration, and in others by secondary amputation, pyæmia, and death. This plan, therefore, has not been received with favor.

The apparatus that seems best to meet the difficulties of the case consists of plaster-of-Paris compresses applied with or without a figure-of-8 bandage. A compress can be placed just above the upper margin of the upper fragment, and then with a strip of rubber plaster about eighteen inches in length and one inch in width the compress can be fixed and the fragment drawn down by bringing the strips downward under the calf of the leg. Another compress is placed just beneath the lower margin of the lower fragment, and the compress held in place by a similar strip of plaster, which runs upward under the thigh. These two strips, crossing each other upon the outer and inner sides of the joint, cause the fragments to come in close apposition. A third compress is placed over the entire fractured patella, so as to prevent the tilting upward of the fractured ends. This dressing must be frequently changed, since the plaster is likely to slip, and each day the knee-joint becomes less in diameter, owing to the absorption of the fluid in the joint. The limb can now be placed upon an inclined plane, and the leg and the thigh fastened to the splint by a few rollers of plaster-of-Paris bandages.

Dr. Little employed a similar apparatus in which the adhesive plaster was omitted and a wet plaster roller in the form of a figure of 8 was applied in the same manner as the adhesive plaster already described, and while the plaster was wet the finger and thumb of one hand indentated the plaster above, and the finger and thumb of the other hand likewise indentated the wet plaster bandage on the lower fragment. The fragments were thus pressed together and firmly held until the plaster had finally "set."

FIG. 63.

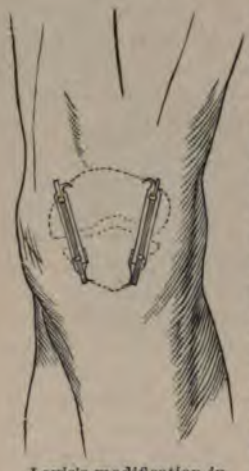
Malgaigne's hooks.

Malgaigne employed a pair of double hooks (Fig. 63), the points of which passed through the integument and pierced the upper and lower fragments. The hooks were now brought close together by means of a screw until the bony surfaces were in coaptation. The method is an ideal one, and the most satisfactory results have been obtained

by these hooks, but it is seldom that a patient will endure the pain and discomfort which they produce.

Levis improved the method by using a double pair of double hooks (Fig. 64), which are placed obliquely; while Trélat, to overcome the objection of pain, substituted gutta-percha plates heated in a flame and accurately adjusted to the fragments, and into these plates the hooks are inserted (Fig. 65).

Fig. 64.



Levis's modification in place.

Hamilton's method "consists of a single inclined plane of sufficient length to support the thigh and leg, and about six inches wider than the limb at the knee. This plane rises from a horizontal floor of the same length and breadth, and is supported at its distal end by an upright piece of board which serves both to lift the plane and to support and steady the foot. The distal end of the inclined plane may be elevated from six to twelve inches according to the length of the limb and to other circumstances. Upon either side, about four inches below the knee, is cut a deep notch. The foot-piece stands at right angles with the inclined plane, and not at right angles with the horizontal floor. Having covered the apparatus with a thick and soft cushion carefully adapted to all the irregularities of the thigh and leg, especial care being taken to fill completely the space under the knee, the whole limb is now laid upon it, and the foot gently

Fig. 65.

Trélat's dressing for fracture of patella.

secured to the foot-board, between which and the foot another cushion is placed. The body of the patient should also be flexed upon the thigh, so as the more effectually to relax the quadriceps femoris muscle. A roller is now applied to the knee by oblique and circular turns, commencing above the patella, and traversing the notch in the splint, each successive turn covering more of the front of the knee until the whole is enclosed. With a second roller the entire limb must then be secured to the splint, this roller extending from the ankle to the groin" (Fig. 66).

Agnew's method consists of "a piece of splint somewhat convex longitudinally, on the upper surface thirty inches long and five inches wide at one end, tapering to four inches at the other. On each side, a

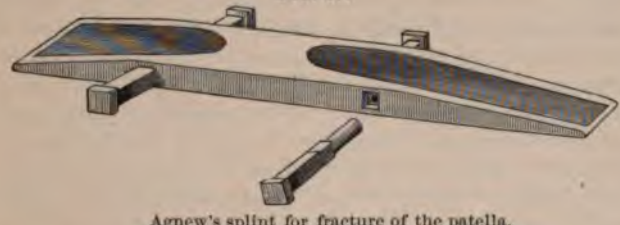
short distance above and below the middle of the board, are to be bored two holes, into which are fitted four pegs with square heads (Figs. 67,

FIG. 66.

Hamilton's wooden inclined plane, to be used only in exceptional cases.

68). This splint must be well padded and placed under the thigh and the leg, the limb being at the same time moderately elevated. Below the knee and the lower fragment are next to be applied, partially over-

FIG. 67.



Agnew's splint for fracture of the patella.

lapping each other, two or three strips of adhesive plaster, each three-quarters of an inch wide and thirteen inches long. These strips are brought together at their extremities and wrapped around the upper

FIG. 68.

Agnew's splint applied.

pegs. This secures in position the lower fragment. Five strips of plaster of like length and width are next applied three or four inches above the knee, descending toward the joint, each strip overlapping one-

third of the preceding one. Bringing the ends of
they are to be wound around the lower pin, when, l
ing the pegs of the two sides, the lower fragment
near apposition with the upper. To prevent the b
tilting forward a broad strip of plaster may be dr
approximation and fastened to the splint below
applied above and below, which secures the thigh
(Fig. 68). As the swelling subsides all that is
the adjustment is to tighten the strips by screwing
they are fastened. By this plan the removal of
dered unnecessary until the cure is complete. Be
fourth weeks the strips may be separated from the
moved so as to overcome stiffening, and the dres
This process should be repeated every five or six
week, when the splint may be laid aside and the
crutches." [1]

Wiring the patella is an operation which within
brought prominently into notice, especially throug
Charles Phelps. The operation is one about which
sity of opinion exists. The arguments in favor of
absence of great danger to life and limb, the super
the function of the joint, and the greater rapidity
ence to the danger to life, it may be stated that Dr
1890) 116 cases of wiring the patella in New York
was no death directly attributed to the operation, a
to delirium tremens—a complication that would h
other operation. In the hands of a thorough asepti
to life from sepsis is insignificant. The superior
function of the limb are demonstrated by the in
bony union and a freely movable joint. The rapid
of repair is made evident when it is considered
walked well within three weeks after the operation
within six weeks, and later on have played footb

On the other hand, some surgeons claim that the
ous, and that results which are sufficiently satisfac
by less severe measures. The author feels justifi
the operation in cases where there is no organic dis
sible antiseptic precaution can be secured, and wh
cumstances of the patient make it an object to as
risk for a maximum of good. It is a serious matt
with rent to pay and children to feed and clothe
three months, and then be practically incapacitate
eighteen months, instead of resuming work within
time of the accident. The question, however, of wi
rest upon the individual circumstances in each case,
is universal can be formulated.

In investigating the history of this operation
Rhea Barton in 1834, McClellan in 1838, Coope
Logan and Green, wired the patella. All of these
and unsuccessful, were performed at a period which

[1] Agnew's *Surgery*, vol. i. p. 974.

suggestion and practice nearly forty years, and, though the principle upon which the operation is now performed is widely different from that which inspired the early pioneers in American surgery, yet the fact is that here this operation was conceived and born, but in Scotland it has developed.

Wiring the patella should not be performed immediately after the accident, as inflammatory action is likely to follow the receipt of the injury. It is wise to wait eight or ten days until the parts are in better condition. In case the fracture is compound, the operation should be performed without delay. Before wiring the fragments of a fracture of the patella the entire limb, including the foot, should be thoroughly scrubbed and washed with soap and hot water, after which ablution the parts should be carefully washed in a solution of bichloride of mercury of about the strength of 1 : 2000. Over the joint itself a saturated solution of iodoform in ether or of naphthalin in ether should be poured. The parts above and below the joint are surrounded and enveloped by towels saturated in a solution of bichloride of mercury of the strength of 1 : 2000. The opposite leg is covered by wet towels, and the parts are in readiness for the surgeon. From the beginning to the end of the operation continuous irrigation of the interior of the joint is kept up with a 1 : 10,000 solution of bichloride of mercury. It is unnecessary to add that the operator and his assistants are thoroughly disinfected, and all instruments, wire, sutures, ligatures, and sponges are prepared with the greatest care. The incision can be either longitudinal, transverse, or crucial. The transverse incision is preferred, though the longitudinal is the one more frequently employed. The fragments and the joint are freely exposed, and all blood-clots from the joint, from the synovial pouch under the quadriceps extensor muscle, and from between the fragments are removed. The two fragments are refreshed by being scraped with a Heber scoop, and the intervening tissue, consisting of the anterior fibrous capsule, is elevated from between the fragments. The Archimedean drill is now made to perforate the upper fragment, and then the lower fragment, care being taken to have the point of the drill emerge from the lower surface of the patella just above the lower cartilaginous surface. In case one fragment is very small, it should be drilled first, so as to bring it into better apposition with the larger fragment. The bottom of the synovial pouch is felt upon its outer side, and an opening made, through which a red-rubber drainage-tube, which contains no free sulphur, is inserted into the cavity of the joint. This tube should be removed in three or four days, although Fowler has demonstrated, in his wonderfully successful case of compound fracture of the patella, that it is possible to allow the tube to remain two weeks with impunity. The wire, which should be of silver, is of moderate thickness, and is twisted and cut off and hammered down upon and into the tissues over the line of fracture. Experience shows that no harm ever results from burying the wire in the tissues of the wound. The aponeurotic fascia and soft tissues in front of the patella are now nicely sutured, which procedure hermetically seals in twenty-four hours the front of the joint from any serous discharge infiltrating through the fissure made by the fracture from the soft parts over the front of the patella. All loose pieces of tissue are removed and any torn or lacerated shreds are cut away by a pair of scissors. The integument is now sutured

and the line of incision is closed. The linear incision can be painted over with a layer of styptic collodion and then dusted over with iodoform or naphthalin. A posterior splint is now adjusted, and a regular plaster-of-Paris splint is applied over the layers of antiseptic dressings. At the expiration of three days the tube is removed through a fenestra cut in the splint. Instead of a plaster-of-Paris splint, a wire-netting splint is used by some surgeons. The patient is now kept in bed, though he can sit up very soon after the operation, and the first dressing should be removed in the course of the first week. In four weeks he can be allowed to get up from his bed, and shortly after walk about the ward. Massage, shampooing, friction, electricity, and gentle passive motion will soon restore the joint to its perfect function.

The conclusions, after a careful analysis and study of all the reported and as many unreported cases, are these:

In compound fractures of the patella there is not the slightest question as to the propriety of the operation of wiring the fragments.

In recent and old fractures, with the facts fully presented to the patient and under the strictest antiseptic precautions, the operation, in the light of present statistics, is wholly justifiable.

In debilitated patients and in those suffering from any organic disease the operation should not be employed, and is, in fact, contraindicated, as are all other operations of expediency.

It is not an operation which can be indiscriminately performed, and never by an ordinary practitioner with little surgical experience and with little faith in the germ-theory of inflammation.

The success of this operation depends wholly upon conscientiously carrying out the smallest details needed to secure asepticity, and the surgeon who is not imbued with the true spirit of antiseptic surgery ought not to perform this operation.

While the number of cases yet operated upon is too limited to admit of deductions by means of which a final settlement of this question can be made in the minds of surgeons, the future practice of the surgery of this and of other countries will soon enable us to condemn it as an unsafe and unjustifiable procedure, or else it will be conceded as one of the grandest triumphs of our art.

Compound fracture of the patella is a most serious accident. There is but one method universally recommended, and that is, under the influence of an anæsthetic, to enlarge the original wound, irrigate thoroughly the joint, drain it with rubber tubing, and wire the fragments with silver wire. If the operation is performed with aseptic precautions, the tubes can be removed upon the third day and the wound closed, and an ideal result secured. This injury in pre-antiseptic days was usually attended by a fatal result, but with the application of the principles of modern surgery the cases, as a rule, do well, and the final result is perfect as regards the restoration of the function of the joint.

FRACTURES OF THE FEMUR form about 6 per cent. of all fractures. In the aged they occur usually in the upper third, in children in the middle third, while in adults the fractures are generally found in the lower third of the bone. Fractures of the shaft, however, may occur at all ages, but fractures of the neck of the thigh-bone are usually found in the aged, and especially in women.

Fractures of the femur in the upper third may be classified according to the seat of the fracture; thus, intra-capsular and extra-capsular fracture of the cervix femoris; trochanteric fracture and subtrochanteric fracture of the shaft; in the middle third according to the variety of the fracture; thus, simple, compound, comminuted, gunshot, and complicated fracture; in the lower third according to the part fractured; thus, external, internal, and supracondyloid fracture and epiphyseal separation.

Epiphyseal separation is an injury which is classified with fractures for reasons already mentioned. This injury occurs before the twentieth year of life, at which time the lower epiphysis unites to the shaft, and any injury of the lower part of the bone occurring as the result of accident or during an attempt to break up ankylosis of the knee in a patient under twenty with the symptoms of fracture suggests a separation of the epiphysis from the diaphysis. In the discussion of supracondyloid fracture the treatment of epiphyseal separation will be considered.

Supracondyloid fracture occurs about two inches above the epiphyseal line, and is usually the result of direct violence, as a blow upon the side of the femur or a blow upon the patella while the knee is flexed. The fracture is situated at the point where the cancellated bone tissue joins the compact bone tissue.

The **signs and symptoms** are the same as in any fracture, with the additional sign of loss of contour of the knee-joint. The femoral artery may be wounded in this fracture, causing a false aneurism, which is of serious import.

FIG. 69.

Fracture of the lower part of the femur.

The displacement consists of flexion of the lower fragment on its transverse axis by the action of the (Fig. 69) gastrocnemius, plantaris, and popliteus muscles, while the rectus and hamstring muscles tend to pull the

FIG. 70.

Intercondyloid fracture of the femur.

lower fragment upward, and the abductor muscles draw the upper fragment inward. The lower fragment drops backward with the upper end of the tibia, while the patella is thrown forward. This causes the lower end of the upper fragment to rest upon the an-

plane, or by artificial means, by division of the tendo Achillis, which secures physiological rest to the limb by causing a temporary paralysis of the muscles, and thus preventing them from contracting and drawing down the lower fragment. Extension should never be employed in the straight position, since this has a tendency to intensify (Fig. 71) the displacement and cause permanent ankylosis in the knee-joint. The leg and thigh can be placed in a wire cuirass, which is bent to represent a double-inclined plane, or Nathan Smith's anterior splint (Fig. 72) can be used, or plaster of Paris can be applied with the knee-joint slightly flexed. In case the fracture is compound, the wound must be made thoroughly aseptic, and free drainage of the knee-joint, with complete immobilization, must be employed.

Internal condyloid fracture (Fig. 73) is produced by direct violence through a fall upon the bent knee, or by a blow upon the condyle, or by a severe lateral wrench. The accident may be serious on account of the proximity of the knee-joint to the fracture.

FIG. 73.

Fracture of the internal condyle of the femur.

The **signs and symptoms** are the same as are found in ordinary fractures, such as localized pain, ecchymosis, crepitus, and mobility of fragments. The length of the limb is not altered, but the normal contour of the joint is destroyed.

The **treatment** consists in placing the entire limb in the straight position and applying some evaporating lotion over the knee-joint for a few days, so as to modify the inflammatory reaction. The fragment must then be adjusted in its proper place and held *in situ* by compresses. Flexion of the knee has a tendency to displace the fragment upward. Ankylosis is apt to follow unless the joint is subjected to gentle passive motion at the end of three weeks. The important clinical fact must not be overlooked that the fragment may fail to unite, and suppuration of the knee-joint has been observed in a few cases. Such a complication calls for the practice of bold antiseptic surgery. Aspiration of the joint in this fracture is unwise, since it might lead to serious joint-complication.

External condyloid fracture is caused by a blow or a fall upon the condyle when the knee is flexed, and, like fracture of the internal condyle, may be serious on account of its close proximity to the knee-joint.

The **signs and symptoms** are the same as in internal condyloid fracture, and the **treatment** mentioned for one is applicable to the other.

Fractures of the shaft of the femur usually occur about the centre of the bone. They are generally oblique, with the line of fracture in the antero-posterior direction. They are caused by direct or indirect violence or by muscular action. Direct violence causes fractures in the lower third; direct and indirect violence, as well as muscular action, may cause fractures in the middle third; while fractures in the upper third of the bone are generally the result of indirect violence. Fractures of

terior surface of the lower fragment. This displacement can be overcome in one of two ways: either by division of the tendo Achillis or by the use of the double incline plane. The contour of the joint is so destroyed by effusion, especially when the upper margin of the upper

FIG. 71.

Union with deformity in supracondyloid fracture.

fragment has wounded the cul-de-sac extending upward upon the front of the femur, that the diagnosis is rendered extremely difficult unless it is made immediately after the injury, before swelling supervenes. It occasionally happens that the joint becomes involved by the fracture

FIG. 72.

Nathan R. Smith's anterior splint.

assuming a T-shape (Fig. 70) and thus extending into the joint through the intercondyloid notch.

The **treatment** of supracondyloid fracture, as well as of epiphyseal separation, is conducted upon one of two principles: either by relaxing by natural means the hamstring muscles by the use of a double-inclined

plane, or by artificial means, by division of the tendo Achillis, which secures physiological rest to the limb by causing a temporary paralysis of the muscles, and thus preventing them from contracting and drawing down the lower fragment. Extension should never be employed in the straight position, since this has a tendency to intensify (Fig. 71) the displacement and cause permanent ankylosis in the knee-joint. The leg and thigh can be placed in a wire cuirass, which is bent to represent a double-inclined plane, or Nathan Smith's anterior splint (Fig. 72) can be used, or plaster of Paris can be applied with the knee-joint slightly flexed. In case the fracture is compound, the wound must be made thoroughly aseptic, and free drainage of the knee-joint, with complete immobilization, must be employed.

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the thigh in its lower third by direct violence may be associated with injury to the femoral artery and vein, which lie in close proximity to the posterior surface of the bone.

The displacement in fracture of the femur is influenced somewhat by the position of the fracture. For general purposes it may be stated that the lower fragment is drawn upward and to the inner or outer side of the upper fragment, and is rotated outward (Fig. 74). This displace-

FIG. 74.

Displacement in fractures of shaft of femur.

ment is due to the action of the vastus externus, vastus internus crureus, adductor magnus, and adductor longus muscles. The upper fragment is flexed by the action of the psoas and iliacus muscles, and abducted (Fig. 75) by the external rotators of the thigh. It occasionally happens

FIG. 75.

Displacement on account of action of psoas and iliacus muscles and external rotators.

that instead of eversion of the foot inversion of this member is produced, due either to the fact that the fracture is impacted or else to the action of the pectineus and adductor brevis.

The **signs and symptoms** of fracture of the shaft of the femur consist of shortening of the limb to the extent of from one to three inches, swelling at the seat of fracture, absolute inability to raise or rotate the limb, ecchymosis, crepitus, localized tenderness and pain, slight flexion and abduction of the upper fragment, and, finally, unnatural mobility. Synovitis of the knee-joint often occurs in fractures of the shaft, and has been variously ascribed to extravasation of blood into the joint, or to a concomitant sprain, or to a disturbance of the venous circulation.

The **prognosis** in fracture of the shaft varies according to circum-

stances. The injury in any case is more or less serious, since it confines the patient to bed for many weeks, compels him to rely upon crutches for some time, and finally may cause permanent lameness from shortening. In compound fracture the prognosis is exceedingly grave, owing to the shock from which the patient suffers. The author has seen death result in consequence of shock incident to simple fracture, but, on the other hand, has treated several cases of double compound fracture of both thighs in which but little shock was present and the patients made excellent recoveries. If the fracture is complicated with an injury to the femoral vessels or a laceration of the main nerve-trunk, the prognosis is most serious, since gangrene may occur.

The **treatment** of fracture of the shaft of the femur is somewhat complex, on account of the many different varieties of fracture which present themselves, as well as owing to the multifarious methods still in vogue. The indications are to overcome shortening, to control muscular pain and spasm, and to produce fixation of the fragments.

FIG. 76.

Adhesive plaster applied for extension.

It seems wholly unnecessary to review the older methods of treatment, since the recent ones are generally accepted as far superior in every respect. The first indication—viz. to overcome shortening—is

FIG. 77.

Extension apparatus for fracture of the thigh (modified from Gurdon Buck).

met by the use of the weight and pulley (Fig. 77), known as Buck's extension method. The amount of weight required depends upon the age of the individual, the amount of muscular rigidity to be overcome, and the

direction of the fracture. In applying the adhesive plaster to the limb the strip should extend above the knee-joint and nearly up to the seat of fracture, since this gives less freedom of motion and takes the strain off from the knee-joint. The amount of weight required to overcome the shortening varies from five to twenty-five pounds. The less weight that is used, the more likely it is that the patient will tolerate the extension for a long time (Fig. 77). The counter-extension is made by elevation of the foot of the bed. Another method of maintaining extension to overcome shortening is by the use of a spica of plaster-of-Paris bandage applied while the muscles are relaxed during anæsthesia. This extension is maintained by the use of strips of perforated zinc or tin under the plaster, and applied according to Fluhrer's method. Still other methods are by the vertical extension of the thigh (Fig. 78); or by Liston's long splint with its perineal band, consisting of a tubular bag filled with wool or a soft pad made of leather; or by Owen Thomas's hip-splint; or by the stirrup of Brown or Cripps; or, finally, by Nathan R. Smith's anterior splint.

FIG. 78.

Fracture of the femur in a child treated by vertical extension.

The next indication—viz. to control muscular spasm and pain—is best met by the use of a long splint to which the thigh can be bandaged, and the entire limb thus kept in its proper relation to the trunk. If the muscular spasm and irritability are severe and cause much pain, tenotomy of the hamstring muscles will at once relieve this condition.

The last indication is met by the use of coaptation splints, four in number, placed around the thigh over the seat of fracture. They should be two inches wide and about eight inches long, well padded and fixed to the limb by strips of adhesive or rubber plaster about one inch in width.

In case of fracture of the thigh in children, employ either the spica of

FIG. 79.

Hamilton's splint for fracture of the femur in children.

plaster-of-Paris bandage with Fluhrer's perforated strips, or Hamilton's double splint (Fig. 79), consisting of two long straight splints connected below the foot by a cross-piece, and extending on both sides from below

the feet to the axillæ, with the limbs bandaged to the thigh. Children with fracture of the thigh can be carried about in this dressing, and are therefore not so much confined as by the other method.

Fracture just below the trochanter is substantially a fracture of the shaft of the bone in its upper part, and special consideration is given to it only because it permits of but one kind of treatment. The upper fragment is tilted upward and abducted by the action of the psoas and iliacus, which are inserted into the process, and abducted by the external rotators. The lower fragment is abducted and drawn up by the extensor muscles.

The **treatment** consists in placing the limb in an apparatus which will cause the axis of the lower fragment to conform to that of the upper or small fragment. This can be accomplished only by the use of a double-inclined plane, and the shortening must be overcome by Buck's extension, which is applied to the lower fragment. The upright over or through which the pulley runs must be placed several feet above the level of the foot of the bed, so that the traction is in the line of the long axis of the femur while resting upon the upward plane of a McIntyre splint. This method must be observed in order to prevent union of the fragments with angular deformity.

Fracture of the trochanter major is caused by a blow direct upon the process or by a fall upon it. The fragment is displaced by the action of the external rotator muscles, which draw the fragment upward and backward.

The **signs and symptoms** of this fracture are those found in ordinary

FIG. 80.

Fracture of trochanter major.

fractures, with the exception that, while there is no shortening in the limb itself, the line in Bryant's triangle is shortened the same as in fracture of the neck of the thigh-bone (Fig. 80).

The **treatment** consists in abducting the limb of the affected side and

placing a compress above and behind the fragment. The compress is to be kept in place by strips of rubber or adhesive plaster.

Extra-capsular fracture of the cervix femoris generally occurs as a result of direct violence, either by a blow upon the trochanter major or else by a fall upon the hip. The weight of the body in falling comes directly upon the neck of the thigh-bone, and, since the neck is attached obliquely to the shaft, the force of the fall or blow is transmitted to it and a fracture follows. If the force which produces the fracture continues to act, the compact tissue of the neck of the bone is driven firmly into the loose cancellated tissue of the trochanter, and an impacted fracture is produced. The direction of the fracture in front is along the insertion of the capsular ligament, which is the anterior intertrochanteric line, and behind the fracture is outside of the capsule, but just internal to the posterior intertrochanteric line (Fig. 81). In many cases the line of fracture is

FIG. 81.

Intra- and extra-capsular fracture of neck of femur.

found to be partly within and partly without the capsule of the joint, and in some cases there are several distinct fragments—viz. one composed of the head and neck of the bone, another of the trochanter, while still another may consist of a part of the shaft of the bone.

Before entering upon a study of the signs and symptoms of extra-capsular fracture of the neck of the thigh-bone it is necessary to explain Bryant's triangle and Nélaton's line, with a view to a complete understanding of the nature of this injury. This knowledge will be useful in

considering all injuries about the hip-joint, and therefore will be introduced in connection with a study of this special variety of fracture.

Bryant's ilio-femoral triangle is formed by drawing a line from the anterior superior spinous process of the ilium to the trochanter major as line A, B, and another line perpendicularly from the anterior superior spinous process to a point on a level with the termination of line A, B,

FIG. 82.

Bryant's ilio-femoral triangle, for diagnosis of fracture of the neck of the femur.

as in line A, C. A third line, C, B, joining these two points of termination in a normal joint measures about two and a half inches (Fig. 82). In case of fracture the base line is less than two and a half inches, or less than a corresponding line in a triangle upon the opposite hip.

Nélaton's line is drawn from the anterior superior spinous process of the ilium to the tuberosity of the ischium, and should in the normal joint just touch the upper border of the trochanter major. In case of fracture or dorsal dislocation of the hip-joint the upper border of the trochanter major is above Nélaton's line.

The **signs and symptoms** of extra-capsular fracture of the neck of the thigh-bone consist of crepitus, elicited by placing the palm of the hand over the trochanter major during forced rotation of the thigh, superficial pain, tenderness and swelling, shortening of the limb to the extent of about two and a half inches, rotation outward of the thigh, and complete eversion of the foot, with contusion and ecchymosis over the joint. The arc of the circle transcribed by the trochanter major is less than it is over the sound joint, since the trochanter major moves upon a shorter radius. These signs, together with the history that the patient has received a severe fall directly upon the trochanter major or a blow transversely applied, and is, as a rule, under fifty years of age, indicate this form of fracture. In case the fracture is impacted many of the signs mentioned are not present. The trochanter is often broadened or enlarged, while its relation to the base line in Bryant's triangle is altered. Another sign of extra-capsular fracture of the thigh-bone has been pointed out by Allis—viz. the relaxation of the fascia lata.

The **prognosis** is serious as regards life, since in some cases pneumonia, bronchitis, fat-embolism, pulmonary thrombosis, inanition, bedsores, or traumatic delirium destroys the life of the patient. In other cases the prognosis is unfavorable in regard to the function of the limb, which is more or less impaired. As a rule, a person over seventy years of age with a fracture of the neck of the thigh will be permanently a cripple, and often bedridden.

The **treatment** of extra-capsular fracture consists in the application

of a plaster-of-Paris spica to the hip while extension is made during anæsthesia. The limb within the splint is prevented from retracting by the use of perforated strips of zinc or tin adjusted to the outer side of the splint between the layers of plaster.

Another method of treatment is by Liston's long splint in conjunction with the weight-and-pulley apparatus, as described in connection with fractures of the shaft of the femur.

This fracture usually unites firmly, and the result is satisfactory except in old persons, but occasionally there is some slight rigidity in the hip-joint.

The **prognosis** as regards recovery and usefulness of the limb is in marked contrast to the result usually obtained in the intra-capsular fracture.

Intra-capsular fracture of the neck of the thigh-bone is of frequent occurrence, and is usually seen in elderly people, chiefly in women. The frequency of this fracture in the aged is ascribed to certain senile changes which take place in the bone itself or in the angle which the neck of the bone assumes to the shaft late in life. In the young and during adult life this angle is oblique, while in the aged it becomes almost a right angle, and the head of the bone is sunk below the level of the top of the trochanter. Besides the changes in regard to the angle at which the neck is placed to the shaft the cancellated tissue undergoes a senile atrophy owing to fatty degeneration, and the compact bony tissue becomes thin and fragile. This fracture is generally caused by some slight injury, such as tripping the toe over the threshold of the door, or slipping upon a rug or over a curbstone, or even turning suddenly over in bed. The seat of the fracture, as its name implies, is within the capsule of the joint (Fig. 83). This fracture is occasionally impacted, and in this case the neck of the bone is driven into the cancellated tissue of the head of the bone. Impaction, however, is rare as compared with the same condition as found in the extra-capsular fracture.

FIG. 83.

Intra-capsular fracture of the neck of the femur.

The **signs and symptoms** of intra-capsular fracture of the neck of the thigh-bone consist of crepitus and pain which are deep-seated, and shortening of the limb to the extent of an inch at first, and subsequently more on account of atrophy and absorption of the neck; shortening of the base line in Bryant's triangle; the projection of the trochanter major above Nélaton's line, thus producing a closer proximity to the crest of the ilium; alteration in the shape of the hip, manifested by flattening of the trochanter, and in the axis of the limb; relaxation of the fascia lata, tensor vaginæ femoris, and gluteus medius muscles; puckering of the integument over the ligamentum patellæ, due to shortening of the limb; outward rotation of limb and eversion of foot, due to a mechanical cause, since the centre of gravity is below a line drawn from the a-

tabulum to the heel, and the weight of the limb thus falls outward; and also to a physiological cause, since the external rotators act upon the lower fragment; and the absence of the ecchymosis over the joint which is seen in extra-capsular fracture. The arc of the circle transcribed by the trochanter major is greater than in the extra-capsular fracture, but less than upon the opposite side, owing to a shorter radius. These signs, together with the history of a slight fall upon the knee or foot in an aged individual, especially a woman, make the diagnosis certain. If inversion of the foot occurs, it is exceptional, and is due to impaction of the fragments or possibly to a paralysis of the external rotators; which condition may be the result of an injury received at the same time as the fracture.

The **treatment** of intra-capsular fracture, as a rule, is unsatisfactory, since the patients, on account of their age, are usually in poor physical condition, and hence the reparative process is retarded. The fracture generally fails to unite, owing to the non-approximation of the fragments, to the enfeebled condition of the patient, to a lack of sufficient arterial supply, and to the presence of synovia between the fragments.

The surgeon must not mistake for an intra-capsular fracture a dislocation of the hip, the differential points of which are presented at length under Dislocation. In contusion of the hip-joint the presence of the head of the bone in the acetabulum and the absence of all the characteristic signs belonging to fracture serve to render the diagnosis clear. A fracture within the capsule can be diagnosticated if the head of the bone is in the acetabulum and immediate shortening has occurred, for under these circumstances, unless the fragments are impacted, crepitus, eversion of the foot, shortening of the limb, and loss of function are always present, and make the diagnosis certain and the special line of treatment perfectly clear. The surgeon should make a judicious choice as to the special method by which a patient with this injury is to be treated. If the patient is in good physical condition, not too aged, and not of a nervous temperament, an attempt should be made to secure union in the fracture. To this end a long Liston splint should be adjusted, and a weight and pulley attached to the foot in order to steady the leg and overcome a certain amount of shortening. During the period of repair attention must be directed to the avoidance of bed-sores and to the maintenance of the general health, upon which so much depends in the management of these cases. All parts of the body must be kept strictly and absolutely clean, and the patient supported by the most nutritious diet, with judicious stimulation if necessary. Anodynes may be indicated in case of loss of sleep or to control pain, while remedies to aid digestion and tonics containing the hypophosphites of lime and soda can be employed with advantage.

In some cases this fracture can be treated by a plaster-of-Paris spica, which is a form of dressing which does not confine the patient to the bed, but permits him or her to rest on a lounge or even to be moved around in a roller chair. Great care must be exercised lest the splint produce excoriation of the skin in elderly people, since this will lead to the formation of bed-sores, a most unfortunate, painful, and often fatal complication. In other cases patients are intolerant of the use of any

splint or dressing, and seem more comfortable without any fixed apparatus, except perhaps sand-bags, which serve to prevent rotation of the limb. A light weight applied to the foot will sometimes help to keep the fracture quiet and afford the patient relief.

It has been suggested to unite the broken surfaces by ivory pegs, but this operation is one of a serious nature and of doubtful expediency in the aged. The best result that can be attained is often very unsatisfactory, and in many cases the patients succumb from the effects of this injury. If the fracture is impacted and the patient is in good physical condition, occasionally an excellent result follows.

FRACTURES OF THE PELVIS form considerably less than 1 per cent. of the fractures, and derive their chief importance from accompanying injury to the pelvic viscera. In this respect fractures of the pelvis resemble fractures of the skull, in which the gravity is influenced not so much by the extent of the fracture as by the damage sustained by the contents of the skull.

Fractures of the pelvis (Fig. 84) may be situated along the crest of

FIG. 84.

Fracture of the pelvis.

the ilium, in the pelvic basin, or in the acetabulum. Fractures involving the crest of the ilium are usually produced by direct violence, as by the passage of a wagon-wheel across the pelvis, or by a heavy weight falling upon the patient, or by crushing while in the act of coupling cars.

The signs of this fracture are pain, crepitus, ecchymosis, and inability to move the muscles attached to the ilium.

The **treatment** consists in keeping the patient quiet in bed and the application of a long Liston splint reaching from the axilla to the foot. The fragments themselves can be adjusted and held *in sitû* by the application of pads or compresses, which are retained by adhesive plaster, or by a Bavarian plaster-of-Paris splint applied so as to fit all the salient points of the pelvis, or by a gutta-percha or felt splint applied after first moulding it to the sound side.

Fracture of the pelvic basin is usually situated in the pubic bone. The direction of the fracture is through the upper ramus upon the inner side of the pectineal eminence, and then through the lower ramus near the point at which the pubis joins the ischium.

The displacement is very slight, as a rule. Palpation of the outline of the pelvis will often reveal the amount of displacement.

The **prognosis** in this fracture is dependent upon the existence of visceral injury. In the absence of any injury to the viscera suppuration in the loose connective tissue in front of the bladder is a complication that often ensues.

The **signs and symptoms** of fracture of the pelvic basin consist of localized pain, greatly increased upon pressure, inability to elevate the limb, crepitus, ecchymosis, and displacement. In these cases there is usually injury to the pelvic viscera. The urethra may be lacerated as it passes under the arch of the pubis, either by a sharp fragment of bone or by separation of the symphysis. A catheter, thoroughly cleansed and boiled, should be introduced into the urethra down to the seat of the laceration, and then an external perineal urethrotomy performed. It may not be necessary to open into the bladder, but a sound must be passed at stated intervals in the future to avoid the formation of traumatic strictures. A catheter should be immediately introduced into the bladder for the purpose of ascertaining whether a rupture of this viscus has occurred. If clear urine escapes, it is presumptive evidence that the bladder is uninjured. This, however, is not an absolute proof, and further investigation should be made. Eight ounces of Thiersch's antiseptic fluid should be injected into the bladder, and if this exact amount is immediately withdrawn rupture of the bladder is in all probability not present. Even this procedure is not an infallible test, since a rent in the bladder-wall has been found of a valve-like character, so that distention of the bladder closes the opening and no fluid escapes into the peritoneal cavity, although a rupture of the bladder-wall exists. If after a few hours following this examination hæmaturia occurs, some doubt may arise as to the accuracy of the diagnosis. The question then to decide is whether the blood found in the urine has its origin from the bladder, or whether the blood is from the kidney as a result of laceration of this organ. The presence of hæmaturia occurring some hours after a pelvic fracture, the fact that the blood is uniformly mixed with the urine, and not found in clots, as is usual in hemorrhage from the bladder, and the evidence derived from the microscopical examination of the bloody urine, will make absolutely certain the diagnosis as to the source of the hemorrhage and the injury of the viscera.

Hæmaturia, due to an injury to the bladder-wall or to the kidney-substance, must not be mistaken for a hemorrhage from the urethra dependent upon a laceration of this canal at the triangular ligament.

The passage of a sound will enable the surgeon to arrive at a conclusion as to this possible source of hemorrhage. A digital examination of the rectum should be made to ascertain if the pelvic vessels are torn or if the bowel itself has sustained any injury. If the patient is a female, it may be necessary to make a vaginal examination in order to be sure that none of the pelvic organs are injured by the fracture. If the examination reveals the fact that the bladder is injured, a laparotomy should be immediately performed, as first described in detail by Sir Wm. MacCormac, the peritoneal cavity should be irrigated, the wound in the bladder-wall closed, and drainage during repair maintained, either by a tube brought out at the lower angle of the abdominal wound or else by a soft catheter introduced into the urethra and kept aseptically clean.

The management of the fracture itself is conducted upon the same principle as that of fracture of the ilium. The long Liston splint should be applied to both limbs, slight flexion of the knees with moderate extension by the double weight and pulley should be employed, and the adaptation of some form of pliable splint or bandage, such as felt, leather, or plaster of Paris, should be made in order to keep the fragments at rest.

Fractures of the acetabulum may occur simultaneously with a dislocation of the hip, but this special variety of fracture is exceedingly rare. The fracture, when independent of a dislocation, may involve only the rim of the acetabulum, most frequently the posterior lip, or it may involve the floor of the acetabular cavity. It sometimes happens that the head of the femur is driven through the floor of the joint-socket into the pelvic cavity (Fig. 85).

FIG. 85.

Comminuted fracture of the acetabulum.

The **signs and symptoms** of fracture of the acetabulum consist of pain, rendered acute by pressure over the trochanter major; an acute synovitis of the hip-joint, with all the manifestations of effusion within the capsule; the presence of crepitus in some cases; or the evidences of impaction of the head of the bone in other cases. If the head of the bone has been forcibly driven through the floor of the joint-cavity into the pelvic cavity, there are also present the signs of injury of the pelvic viscera.

The **complications** are to be treated according to the rules just laid down in discussing this question in connection with fractures of the pelvic basin. The fracture itself can be best treated by the same method as intra-capsular fracture of the neck of the thigh-bone or a fracture of the pelvic basin.

FRACTURE OF THE HYOID BONE seldom occurs, owing to the mobility of the bone and the protection which is afforded to it by the inferior maxillary bone. These fractures are usually caused by a direct blow upon the neck or by some one throttling the patient in an attempt at violent assault, or by a fall from a height, or during the act of judicial or

suicidal hanging. The junction of the body of the bone with the greater cornu is the usual seat of the fracture. There are some cases recorded where a fracture of this bone has occurred as a result of muscular action.

The **signs and symptoms** are those which are found in common with ordinary fractures of other bones. The patient usually hears a sudden snap, and at the same time experiences, with a sense of suffocation, acute pain. There is usually a slight hemorrhage from the mouth, produced by a laceration of the mucous membrane of the pharynx. Movement of the head is attended with severe pain, and the patient is unable to protrude the tongue. The voice is hoarse, and articulation as well as deglutition becomes very painful. Dyspnœa, expectoration of bloody mucus, and irregularity of the pulse are symptoms often observed.

The **prognosis** is favorable if the fracture of the bone is not associated with injury to the larynx, but when this complication is present nearly 50 per cent. of the cases are fatal. The danger of œdema glottidis must not be lost sight of, since this condition is likely at any time to arise.

Treatment.—An attempt should be made at once to reduce the fragments by placing the left index finger of the surgeon in the patient's mouth, and with the thumb and index finger of the right hand making external pressure until the fragments are brought into apposition. If the parts are not easily brought together, it may be necessary to administer an anæsthetic, during which the surgeon must guard against the danger of the patient swallowing the tongue. The patient's head should now be flexed forward, and held in this position by some retentive apparatus which extends from both sides of the head to the shoulders. A collar consisting of leather or felt or plaster of Paris, like the Bavarian splint, can be placed around the neck and applied to it while wet, so that the collar can adapt itself to the salient points of the neck. The œsophageal tube must be used to feed the patient, who for ten days at least must not be allowed to talk.

FIG. 86.

Œdema of the glottis.

Œdema glottidis (Fig. 86) is a complication that may arise at any moment, and if inflammation or dyspnœa is present a prophylactic tracheotomy should be immediately performed. If the soft parts within the mouth are lacerated and there is much ecchymosis externally, it is best to perform a prophylactic tracheotomy, as it is unsafe to delay this operation until œdema glottidis is established, as in these cases death occurs instantly and without any warning.

FRACTURE OF THE RIB occurs in the proportion of about 18 per cent. of all fractures. This fracture is frequent in adults, but very infrequent in children, owing to the elasticity of the cartilage connecting the rib to the sternum and the strength of the ligament connecting the rib to the vertebra. The elasticity is so great in children that the arch yields without breaking upon the application of violent pressure. A carriage has been known to pass over the chest of a child, and on

account of the elasticity no fracture occurred. In the aged this elasticity is lost, owing to a certain amount of ossification of the cartilage and to senile atrophy of the rib itself, which causes it to be fragile and inelastic. The ribs of the insane are said to be very brittle, owing to the great proportion of earthy to organic matter.

The ribs most frequently fractured are from the fourth to the eighth, the seventh rib being the one most frequently found to be the seat of fracture. The upper ribs are protected from injury by the pectoral muscles and the clavicle, while the lower or false ribs yield on account of their great mobility. Indeed, fractures of the first and last ribs are almost unknown. The fracture is usually at or near the angle of the rib and about four inches from its attachment to the vertebral column, since at this point the two forces, the blow and the recoil, meet. Occasionally, however, a fracture is found near the junction of the costal cartilage.

The **cause** of fracture of the rib may be direct violence, as when the rib is struck and the fragments are driven inward. In this variety of fracture the pleura and lung may be injured. The fracture may also be caused by indirect violence, as when the chest is suddenly compressed and the fragments are driven outward and snap. Finally, fracture of the rib has been caused by muscular action during the act of parturition. Malgaigne has reported a case of fracture due to the impulse of the heart.

Fractures of the ribs are simple, or compound as in gunshot or stab wound, or complicated, as when the diaphragm, pleura, lung, or the peritoneum is wounded. A complicated fracture of the rib has been observed in a few cases where the fragment injured the heart, or where the chest-cavity has been compressed so as to cause an injury of the heart without an accompanying wound of the pericardium. A complicated fracture of the rib has been observed by the writer in which the patient fractured one of the floating ribs in an attempt to get out of a berth while on shipboard. The patient was thrown violently against the side of the berth and struck the lower rib, which suddenly fractured, and at the same time wounded the peritoneum, so that a traumatic peritonitis was developed; from which attack, however, the patient made an excellent recovery.

The **signs and symptoms** of fracture of the rib may be classified as local and general. Among the local signs are sharp, circumscribed pain, increased upon inspiration by manual pressure applied to the sternum, which causes the fragment to spring out and increase the pain; diaphragmatic and abdominal breathing; crepitus, heard by the stethoscope placed over the fracture, or felt by placing the palm of the hand over the fracture while the patient coughs; and also abnormal outline of the chest side-wall. If the fracture happens to be compound or from a gunshot wound, hemorrhage from the seat of fracture is a prominent sign. This hemorrhage may originate from a wounded intercostal artery, in which case the blood is bright red in color, and comes in spurts synchronous with the action of the heart, or else the hemorrhage may come from wounded lung-tissue, in which case the blood wells up from the bottom of the wound and is very dark in color, due to the presence of carbonic acid.

Among the general signs and symptoms are hæmoptysis, or the ex-

pectoration of blood from the wounded lung; and emphysema, or the escape of air from the lung into the surrounding tissue. The emphysema is first noticed upon the side of the chest-wall, and it may extend to the neck, and even over the abdomen. The writer has on several occasions observed air in the connective tissue as far down as the scrotum, although it is not likely to go below Poupart's ligament. Pneumothorax and hæmothorax also may be present in fracture of the rib. It is apparent that these general signs indicate the presence of a complicated fracture. Occasionally pulmonary apoplexy and pulmonary emphysema may also be found in fracture of the rib.

The **treatment** of fracture of the rib should be directed to the relief of pain, to the diminution of the respiratory movements, to the fixation of the fragments, to the arrest of hemorrhage, and, finally, to the anticipation of, as well as to the control of, inflammatory complications. With a view to the first and second objects opium is indicated. This drug is the sheet-anchor in this fracture, because it not only relieves pain by its specific action and by its reducing the number of the respirations, but it also has a salutary influence upon inflammatory reaction. With a view to accomplishing the third object—viz. the fixation of the fragments—a six-inch broad and a three-feet long strip of rubber or adhesive plaster should be applied around the chest, the centre of which strip should pass over the site of the fracture. The plaster should be tightened during forced expiration, so that upon inspiration the injured chest-wall will have a firm support. This simple apparatus affords the greatest possible comfort to the patient. The hemorrhage, if pulmonary, can be controlled by packing the wound with iodoform gauze in the form of a tampon; if arterial, the wound must be enlarged so as to secure both ends of the divided intercostal artery. In case the vessel cannot be found, a square piece of gauze about the size of a sheet of letter-paper can be introduced into the wound and beyond the rib by forcing it with a director placed in the centre of the piece of gauze. Into this glove-finger-shaped piece of gauze small narrow strips of iodoform gauze can be pushed, and when the bottom of the glove-finger tampon is well filled the entire compress can be partially withdrawn until it comes in contact with the inner surface of the upper and lower ribs in the interspace. The pressure can now be made directly upon the bleeding vessel. This tampon can be subsequently removed by diminishing its size by removing some of the narrow strips of gauze with which the glove-finger has been packed.

The emphysema is not to be interfered with, since the air will eventually become absorbed, and, although the patient may be unrecognizable on account of the general swelling, the condition itself gives no cause for alarm. It occasionally happens that the air is so freely distributed that when it reaches the loose cellular tissue of the neck respiration is seriously embarrassed, and in this case a few incisions through the integument will suffice to allow the air to escape. It is, however, only under extraordinary circumstances that incisions should be made, since this apparently simple procedure has been followed by death. If the emphysema invades the mediastinum or forces its way into the interlobular tissue of the lung, this condition is not amenable to surgical treatment and forms a most serious complication.

In fracture of the ribs in which there is little or no collapse, and the

patient is a strong, plethoric individual and suffering from dyspnœa and impending asphyxia, venesection is indicated, and will remove at once the alarming distress and discomfort, since by this means the venous congestion and pulmonary engorgement are immediately relieved.

The *costal cartilages* may be fractured, either at their junction with the rib or even in the middle of the cartilage itself. The fracture of the cartilage is produced by the same causes as fracture of the ribs, and the signs and symptoms and treatment are similar.

FRACTURE OF THE STERNUM occurs in less than 1 per cent. of all fractures. This is owing to the elasticity afforded to it by its connections with the ribs, and also to its spongy structure. It may be caused by direct violence, as a heavy blow upon the chest, or by a heavy weight falling upon the patient, or by a gunshot wound. This injury has also been observed as the result of indirect violence, as in bending the body suddenly backward or forward, and occasionally a fracture has been observed after a fall upon the shoulder, in which case the force is transmitted along the clavicle and ribs. Several cases of fracture of this bone have been reported as a result of muscular action during labor-pains. A case has also been reported where the patient fractured the sternum by endeavoring to lift a weight with the teeth while the body was placed in the position of opisthotonos.

The fracture is usually simple and transverse, and it is generally situated at the junction of the manubrium with the body of the bone (Fig. 87). If the fracture is due to a gunshot wound, it may of course be situated at any part of the bone. It sometimes happens that the lower extremity of the bone or the ensiform cartilage is the part broken.

The displacement is usually slight, on account of the periosteum in front and behind the bone. The lower fragment is usually displaced forward and overlaps the lower margin of the upper fragment.

The **signs and symptoms** of fracture of the sternum are—fixed pain, which is increased by a deep inspiration or expiration; cough, attended by expectoration of blood and marked irregularity of the action of the heart, with dyspnœa; flexion forward of the head and trunk; change in the outline of the bone; and crepitus, felt by placing the palm of the hand over the sternum while the patient coughs. In some cases, however, crepitus can be detected only by means of the stethoscope.

The **prognosis** in this fracture is favorable, unless it is complicated with a fracture of the spinal column or the ribs or the clavicle, or by a hemorrhage into the anterior mediastinum.

The **treatment** consist in the application of a broad band of adhesive plaster placed around the chest in the manner already described in the dressing of a fractured rib. It may be necessary to apply a compress to the fragment which is tilted forward, and this dressing will maintain the apposition of the fragments. In reducing the fracture the patient should be placed in the position of opisthotonos, with a hard pillow under the back. In this attitude of the body the advancing fragment can be brought into coaptation with the receding fragment. The suggestion of Petit, of cutting down upon the bone and elevating the fragment, or that of Nélaton, of passing a hook under the fragment, is not to be recommended. The dangers of injury to the pleura and pericardium, of suppuration in the anterior mediastinum, and of conversion of a simple into a compound frac-

ture, are too great risks to run to relieve a deformity which ordinarily produces no disturbance. Trephining of the sternum is likewise to be condemned, as well as the use of the gimlet, since these measures have been

FIG. 87.

Displacement of fragments in fracture of sternum.

attended with serious result. The movements of respiration should be diminished by the use of opium, and the patient placed in the position in which he can breathe with the least difficulty.

FRACTURES OF THE CLAVICLE occur in about 15 per cent. of all fractures. They are common, because the bone is prominently exposed, and receives all shocks transmitted to it by falls upon the shoulder, elbow, and hand. This injury also occurs from direct violence, as a blow upon

the shoulder or by a heavy weight falling upon it, and has been known to result from muscular action, on account of the strong contraction of the deltoid and the clavicular portion of the pectoralis major, an example of which is reported in an attempt to lift a carriage-top while seated in the carriage. Fractures of the clavicle are rare in elderly people, and exceedingly common in children, in whom half of the cases occur before the fifth year.

The seat of the fracture may be in the body of the bone or at the acromial or sternal extremity. The most frequent seat of fracture of the clavicle is in the body of the bone just external to the centre, since at this place the bone is least in diameter, and at the same time it is the junction of the outer and sudden curve with the inner curve. This is the case upon exposure to indirect violence, while following direct violence any portion of the bone may be broken; but the sternal end is less frequently broken, since the direct force of a blow upon the shoulder is usually attended by fracture of the acromial end, which receives the full force of the injury.

The fracture is generally simple, although the writer has seen two cases of compound fracture, excluding gunshot fractures. The double curve in the body of the clavicle prevents it from breaking as often as if it were perfectly straight, since the curves transmit the force over a greater space. It is a noteworthy fact that it seldom happens that

FIG. 88.

Displacement of inner and outer fragments in fracture of clavicle.

fracture of the clavicle is associated with other injuries, such as fracture of the adjacent ribs, injury of the pleura, laceration of the important axillary vessels, or stretching of the cords of the brachial plexus. Any or all of these complications may occur, but, considering the frequency of fracture of the clavicle, it is extremely rare to find any of these concomitant injuries.

The displacement in fractures of the clavicle consists of an elevation

and projection of the sternal end of the bone by the action of the clavicular portion of the sterno-cleido-mastoid muscle (Fig. 88), and a depression of the acromial extremity by the weight of the arm and by the action of the pectoralis minor muscle, and also by the lower fibres of the pectoralis major and the deltoid acting from its humeral insertion. The outer fragment is also rotated by the action of the serratus magnus muscle, which has a tendency to draw backward the inner extremity of the outer fragment; which fact explains the frequency with which the fragment perforates the loose skin over the clavicle, and thus causes a compound fracture.

The **signs and symptoms** of fracture of the clavicle vary somewhat according to the special seat of the fracture. Besides the ordinary signs indicative of fracture, there are some special signs and symptoms which are characteristic, among which may be mentioned the interruption in the line of the bone; the loss of power in the muscles attached to it; the flattening and depression of the shoulder, which falls downward by the weight of the arm, inward by the action of the pectoralis minor and the subclavius, and to some extent of the pectoralis major muscle, and forward, on account of the shape of the thorax; and, finally, the turning of the head and neck toward the injured side in order to relax the muscles, which cause pain by their contraction. Among other signs may be mentioned the nearer approach of the affected shoulder to the mesial line of the sternum, the close proximity of the arm to the side of the chest, and the loss of the support of the elbow, which is generally held up by the patient's other hand.

The **treatment** of fracture of the clavicle, on account of its extreme frequency, has commanded the attention of surgeons in every country. The different kinds of apparatus and appliances all aim to bring the shoulder upward, outward, and backward in order to overcome the displacement, which is downward, inward, and forward. If a patient will consent to lie on his back in bed for two weeks upon a firm and hard mattress, with a small pillow under the head, and the affected arm held close to the side of the chest by a long, heavy sand-bag, this supine position will accomplish more satisfactory results than any dressing yet devised. The recumbent position upon the back causes the shoulder to assume its normal relation. A sand-bag placed over the point of the shoulder will assist by depressing it, and thereby bringing the fragments into apposition. The results obtained by this simple method are far superior to those obtained by any other, since the fragments unite without any overlapping and the callus is not so exuberant; and in the case of a lady, in whom the requirements of dress compel her to expose her neck, the disfigurement of a callus is sometimes more dreaded than the forced confinement in bed for two weeks. It is only occasionally that a woman's vanity will induce her to choose this method of treatment.

If the patient will not consent to remain in bed, the best and simplest method is that of Sayre, who describes his dressing in the following manner: "After drawing the arm backward and retaining it there by a strip of adhesive plaster, pass another piece of plaster from the well shoulder across the back, and by pressing the elbow well forward and inward the first plaster around the middle of the arm is made to act as a fulcrum, and the shoulder is necessarily carried upward, outward, and

backward; and the plaster, being carried over the elbow and forearm (which is flexed across the chest) to the opposite shoulder, the place of starting, and then secured by pins or stitches, permanently retains the parts in position. . . . . Strong and good adhesive plaster is cut into two strips three to four inches wide (narrower for children), one piece long enough to surround the arm and go completely around the body, the other to reach from the sound shoulder around the elbow of the fractured side and back to the place of starting. The first piece is passed around the arm just below the axillary margin, and pinned or stitched in the form of a loop sufficiently large to prevent strangulation, leaving a portion on the back of the arm uncased by the plaster. The arm is then drawn downward and backward until the clavicular portion of the pectoralis major muscle is put sufficiently on the stretch to overcome the sterno-cleido-mastoid, and thus pull the inner portion of the clavicle down to its level. The plaster is then carried smoothly and completely around the body, and pinned to itself on the back to prevent slipping, as seen in Fig. 89. The first

FIG. 89.

Sayre's adhesive-plaster dressing for fracture of clavicle (first piece).

FIG. 90.

The same (second piece).

strip of plaster fulfils a double purpose: first, by putting the clavicular portion of the pectoralis major muscle on the stretch, it prevents the clavicle from riding upward; and secondly, acting as a fulcrum at the centre of the arm when the elbow is pressed downward, forward, and inward, it necessarily forces the other extremity of the humerus (and with it the shoulder) upward, outward, and backward; and it is kept in this position by the second strip of plaster, which is applied as follows: Commencing on the front of the shoulder of the sound side, draw it smoothly and diagonally across the back to the elbow of the fractured side, where a slit is made in its middle to receive the projecting olecranon. Before applying this plaster to the elbow an assistant should press the elbow well forward and inward (Fig. 90), and retain it there while

the plaster is continued over the elbow and forearm (pressing the latter close to the chest and securing the hand near the opposite nipple); crossing the shoulder at the place of beginning, it is there secured by two or three pins, as seen in Fig. 90.

"When this has been done the deformity will have entirely disappeared, the fractured bones will be accurately adjusted, and as long as the strips of plaster maintain their position no amount of force can displace them."

FIG. 91.

Velpeau's dressing for fracture of the clavicle.

Velpeau's dressing is made by means of a long roller bandage. The patient's hand is placed upon his opposite shoulder, the elbow against the front of the chest, and a bandage is started in the opposite axilla and carried obliquely across the back over the affected shoulder (Fig. 91), down in front of the arm, and under the elbow to the other axilla. After the arm is thus vertically bandaged and brought snugly against the chest, the roller is carried in a circular manner around the thorax from below upward until the arm and the forearm are covered by this bandage as high as the axilla on the unaffected side permits. This entire dressing can be made stiff by the application of loose plaster or silicate of soda, or even by stitching it in many places, so that the roller will not become displaced by slipping.

Moore's dressing consists of a figure-of-8 bandage (Figs. 92 and

FIG. 92.

Moore's dressing for fractured clavicle.

FIG. 93.

Moore's dressing for fractured clavicle.

93), a detailed description of which, in his own words, is: "I use a shawl or piece of cotton cloth, which, when folded like a cravat eight

inches in breadth at the centre, should be about two yards long. Placing this at the centre across the palm of the surgeon, he seizes with this hand the elbow of the patient which corresponds with the broken clavicle. The two ends of the bandage hang to the floor. The one falling inward toward the patient is carried upward in front of the shoulder and over the back, making a spiral movement in front of the shoulder. This is entrusted to an assistant. The outer end is then carried across the forearm, behind the back, over the opposite shoulder, and around the axilla. This meets the other end, which may be carried under the axilla and over the shoulder of the opposite side, thus making the figure (8) turn around the sound shoulder. This twist, it will be seen, also makes the figure (8) turn around the elbow of the affected side."

FRACTURE OF THE SCAPULA is rare, on account of the mobility of the bone, the elasticity of the ribs, the protection which is afforded to it by the cushion of muscles upon its dorsal surface, and the support which it has from the thoracic wall.

Fractures of the scapula are caused usually by direct violence, although a case has been reported in which the fracture was said to have occurred as a result of muscular action.

The varieties of fracture of the scapula are—of the body, of the acromion process, of the coracoid process, and of the neck of the bone. When the *body* is fractured the line of fracture is usually just below the spinous process (Fig. 94).

FIG. 94.

Fracture of body of scapula.

The **signs and symptoms** are—crepitus, pain, displacement, and ecchymosis. The crepitus is found by placing the palm of one hand

upon the back over the scapula and moving the arm with the other hand.

The displacement consists of the drawing upward and forward of the lower fragment by the action of the serratus magnus and the teres major muscles, and the drawing backward and upward of the upper fragment by the rhomboideus major muscle.

The **treatment** of fracture of the body of the scapula is the same as that described for fracture of the rib, with the addition of a compress over the body of the bone. The above-mentioned muscles causing the displacement should be relaxed by position. It has been suggested to place a gutta-percha mould over the bone, and thus hold it *in situ* until the fracture has been repaired.

Fracture of the acromion process is the result of direct violence, and may involve the tip of the process only or the entire thickness in a transverse or an oblique direction.

The **signs and symptoms** are—pain, crepitus, ecchymosis, flattening and falling downward, forward, and inward of the point of the shoulder, inability to raise the arm, and interruption of the line of the spinous process as felt by the finger passed over the surface. Any movement of the shoulder will be attended with great pain, and crepitus is distinctly felt. These signs are well marked when the fracture of the acromion is behind the acromio-clavicular articulation, but when in front of this ligament the displacement and the signs are not so pronounced.

The **treatment** consists in elevation of the elbow, while at the same time a pad is placed between the elbow and the thoracic wall. The elevation is maintained by a bandage from the elbow to the opposite shoulder. This makes the head of the humerus act as a splint against the broken acromion. A pad should not be placed in the axilla, since this would have a tendency to draw the head of the humerus too far outward, and then it would not act as a splint. The fragment of the acromion should be strapped down by strips of adhesive plaster pulled down with considerable strength. If the patient will submit, a most desirable result can be obtained by placing him upon his back, and then bringing the arm out at a right angle to the trunk. This position relaxes the deltoid muscle and brings the fragment into apposition.

The coracoid process is rarely fractured. The accident is usually the result of direct violence. The apex of the process is pulled downward and inward by the action of the pectoralis minor, the short head of the biceps, and the coraco-brachialis muscles. It sometimes happens that little if any displacement is noticed, since the strong coraco-clavicular ligament remains untorn and the dense periosteal and fibrous tissue holds the fragments in place.

The **signs and symptoms** consist of crepitus, mobility of the process, marked impairment in the movements of the arm, and the stationary position of the fragment when the arm is passively moved.

The **treatment** consists in flexing the forearm upon the arm, and then drawing well forward the elbow upon the antero-lateral part of the chest. This position relaxes the two muscles having their origin from, and insertion into, the coracoid process.

Fracture of the surgical neck of the scapula (Figs. 95, 96) occasionally occurs, and often in conjunction with a fracture of the floor of

the glenoid cavity. The fracture may be situated at the anatomical or surgical neck, the anatomical neck consisting of that part of the bone which is external to the coracoid process, and just behind the glenoid fossa, the surgical neck embracing the anatomical neck and including the coracoid process. Thus a fracture of the anatomical neck

FIG. 95.

Fracture of the neck of the scapula (according to Sir Astley Cooper).

FIG. 96.

Comminuted fracture of the glenoid cavity.

would cause a separation of the glenoid cavity only, while that of the surgical neck would involve the coracoid process. This fact must not be overlooked, since the displacement in case of fracture of the surgical neck is well pronounced, while there is little deformity if only the anatomical neck is fractured. The cause of this fracture is by direct violence, either from a blow upon the shoulder or from a fall from a height in which the patient strikes upon the shoulder.

The **signs and symptoms** consist of a flattening of the shoulder, simulating a dislocation; prominence of the acromion, with a slight sulcus beneath it sufficient to receive the index finger placed laterally under it; lengthening of the arm; the movement of the coracoid process with the humerus; crepitus produced by elevation of the elbow and rotation of the humerus; the complete restoration of the landmarks of the joint by lifting the arm at the elbow, and their immediate loss upon removal of the support; and the presence of the glenoid cavity felt in the axilla.

The **treatment** consists in elevation of the elbow after flexion of the forearm upon the arm, fixation of the scapula by means of compresses held in place by strips of rubber plaster, and the adjustment of a pad in the axilla.

The Velpeau dressing, as used in fracture of the clavicle, is an excellent dressing for this injury, since it supports the arm and causes lateral pressure of the arm to the chest-wall.

FRACTURES OF THE HUMERUS form about 8 per cent. of all fractures, and the classification is similar to that of fractures of the femur: in the upper third, according to the seat of fracture, thus: fracture of the anatomical neck, of the tuberosity, of the surgical neck, and epiphyseal

separation; in the middle third, according to the variety of the fracture, thus: simple, compound, comminuted, and complicated; in the lower third, according to the part fractured, thus: external and internal condyloid fractures, supra-condyloid fracture, and epiphyseal separation.

Fractures of the Lower End of the Humerus.—Epiphyseal Separation.—Epiphyseal separation is likely to happen before the eighteenth year, and may occur in the form of a detachment of the articular extremity from the diaphysis. The condyles remain attached to the shaft, since they undergo ossification by separate centres, or the condyles with the articular extremity may become detached from the shaft of the humerus. In some respects epiphyseal separation resembles a supra-condyloid fracture or a backward dislocation of the forearm. In incomplete epiphyseal separation the forearm is flexed, and assumes a position midway between supination and pronation, while the normal relations which exist between the condyles and the olecranon are destroyed. The measurement of the forearm reveals shortening between the condyles of the humerus and the styloid processes of the radius and the ulna. In the complete epiphyseal separation the relations which exist between the condyles and the olecranon are not disturbed, since the separation occurs above the condyles. The differential points between the fractures in this region on the one hand, and a backward dislocation of the forearm on the other, are the tendency of the deformity to return in fractures as soon as reduced, and the difficulty of maintaining perfect apposition even with suitable splints; also the preternatural mobility, crepitus, shortening of the arm from the acromion to the condyle, and more or less rigidity of the muscles, with ecchymosis over, and swelling in, the elbow-joint.

A dislocation of both bones of the forearm backward is distinguished from epiphyseal separation by immobility, absence of crepitus, no alteration in the length of the shaft of the humerus, the great prominence of the olecranon, which is nearer to the acromion than upon the opposite side, and the greatly altered relations of the olecranon process and the condyles.

The **treatment** of epiphyseal separation is the same as that of supra-condyloid fracture, since the two injuries require practically the same kind of surgical dressing.

Supra-condyloid fracture is usually transverse, but it is at the same time oblique from above downward and forward.

FIG. 97.

Supra-condyloid fracture of the humerus (Hutchinson).

The **signs and symptoms** are in some respects similar to the backward displacement of both bones of the forearm (Figs. 97, 98, and 99). The diagnostic signs of supra-condyloid fracture are the projection of the olecranon, the swelling in front of the elbow-joint, slight flexion of the forearm, pronation of the hand, and inability to flex the forearm. Marked crepitus is elicited by flexion and extension of the forearm. The signs which distinguish this injury from dislocation of both bones of the forearm backward have been enumerated in connection with epiphyseal separation. It sometimes happens that a vertical frac-

ture occurs in connection with the supra-condyloid fracture, in which the line of fracture extends downward between the two condyles, forming what is called a "T-shaped fracture" (Fig. 100). This injury results

Fig. 98.

Supra-condyloid fracture of the humerus.

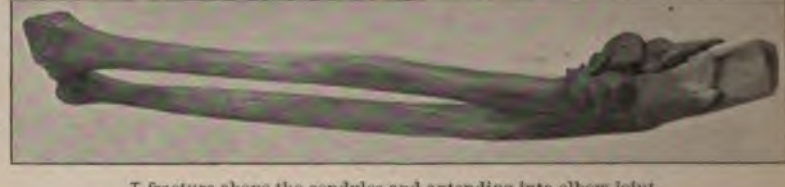
Fig. 99.

Supra-condyloid fracture of the humerus: union with displacement.

from direct violence which is applied posteriorly, and is also seen in gunshot fractures. The additional signs of this complication consist of an increase in the breadth of the condyloid extremity of the lower end of the humerus and severe joint-inflammation attended with great effusion.

The **treatment** of supra-condyloid fracture after complete reduction consists in the application of a well-padded anterior angular splint and a

Fig 100.



T-fracture above the condyles and extending into elbow-joint.

short posterior splint, with the forearm flexed to a right angle upon the arm and the hand placed in the supine position. Some surgeons advise the use of the internal angular splint with the forearm placed midway between pronation and supination and the palm of the hand pointing inward and the thumb upward. Passive motion should not be employed until the end of the fourth week, as the fracture does not extend into the elbow-joint, and such movement before consolidation has taken place is likely to disturb the union of the fragments.

Internal condyloid fracture occurs as a result of direct violence, and the line of fracture generally extends downward and outward to the tro-

chlear surface of the humerus, and passes through the olecranon and coronoid fossæ. The fragment is displaced upward and backward and slightly inward, and it is accompanied by the ulna.

The **signs** are—removal of the internal condyle from its normal position, crepitus, mobility, pain and swelling over the internal condyle, increase in the breadth of the lower end of the humerus (Fig. 101), greater prominence of the ulna posteriorly during extension of the forearm, and a corresponding swelling upon the front of the elbow-joint, due to the projection of the lower end of the humerus.

FIG. 101.

Fracture of the internal epicondyle of the humerus (epitrochlea) (Gurlt).

The **treatment** of this fracture consists in the application of some evaporating lotion over the condyle and the joint with a view to reducing the inflammatory swelling. As soon as the inflammation has subsided the fragment, consisting of the internal condyle, should be placed in its proper position, and held *in sitû* by means of a pad. An angular splint should now be applied, with the forearm flexed upon the arm to a right angle and placed in the position of supination, or midway between pronation and supination, with the thumb upward. In the use of an angular splint the surgeon must guard against any undue pressure, which might cause a slough over any bony prominence or even gangrene of the fingers. Since this fracture involves the elbow-joint, passive motion must be instituted after the second week in order to prevent ankylosis. In case the fracture is T-shaped, cold evaporating lotions should be first applied, and after the subsidence of the inflammation the fragments should be adjusted and the same kind of splint applied. Ankylosis follows, since no passive motion can be made, and the degree of ankylosis depends upon the amount of joint-complication.

FIG. 102.

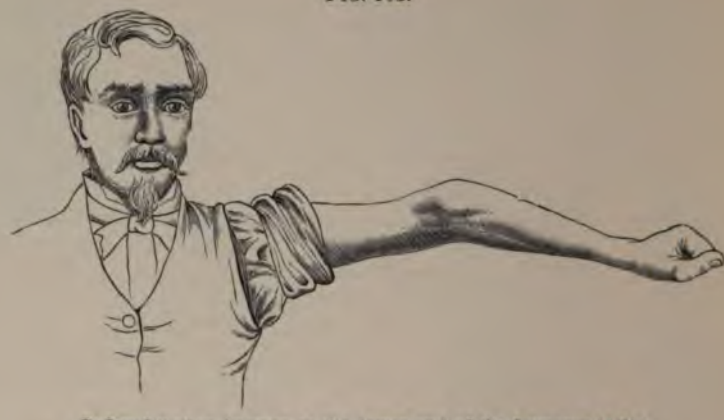
Showing the transmission through the external condyle of a force received upon the palm.

External condyloid fracture is often seen in children. While it may be the result of direct violence, it is more often caused by a fall upon the hand. It usually involves the elbow-joint, or the fracture extends downward and separates the capitellum from the articular surface, and the head and shaft of the radius are driven up against the capitellum. The fragment is displaced upward and backward and slightly outward (Fig. 102). Dr. Oscar H. Allis has called attention to the deformity arising from improper treatment of fractures of the lower end of the humerus (Fig. 103), and has pointed out the important fact that the outward deflection of the forearm is essential to serve for the purpose of the "carrying function" (Fig. 104). The reader is referred to Dr. Allis's interesting monograph upon this subject.[1]

The **signs and symptoms** of fracture of the external condyle are—

[1] *Ann. Anat. and Surg. Soc. Brooklyn*, 1880, ii., 289.

FIG. 103.



Deformity after fracture at the lower end of the humerus (Allis).

pain, swelling over the external condyle, the presence of an ill-defined tumor, tenderness upon pressure, crepitus by pronation and supination of forearm, and sometimes by moving fragment, and finally, impairment in the movement of the joint.

FIG. 104.

The outward deflection of the forearm — the "carrying function."

The **treatment** of this fracture is similar to that employed in fracture of the internal condyle, so that a separate description is unnecessary.

Fracture of the shaft of the humerus is frequently observed, and it is produced by direct as well as by indirect violence, and even by muscular action, and, again, by uterine contraction. It has been produced during the act of parturition. The lower half of the bone is more frequently broken than the upper half, and the line of fracture is generally oblique from above downward and outward. A transverse fracture is more frequent in the humerus than in the other bones. Fractures involving the shaft include all below the surgical neck to the condyles of the bone.

The displacement in fracture of the shaft of the humerus largely depends upon its situation in reference to the attachment of the deltoid muscle. If above the insertion of the deltoid and below the insertion of the pectoralis major, latissimus dorsi, and teres major, the lower fragment is found to lie external to the upper fragment and is drawn upward by the deltoid muscle, while the upper fragment is drawn inward by the action of the pectoralis major, latissimus dorsi, and teres major muscles. If the fracture takes place below the insertion of the deltoid muscle, the lower fragment is drawn to the inner side of the upper fragment by the action of the triceps and biceps muscles, and the upper fragment is abducted by the action of the deltoid, and at the same time drawn forward by the an-

terior fibres of the deltoid and the pectoralis major. There is very little displacement in fractures of the shaft of the humerus in the lower part of the bone, since the broad insertion of the brachialis anticus in front is counterbalanced by the insertion of the triceps behind. These two muscles so completely surround the shaft of the humerus that little or no displacement occurs.

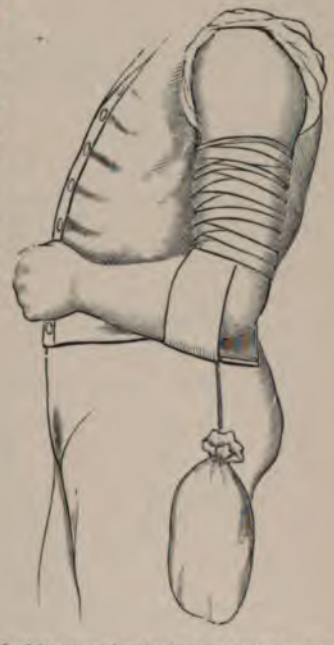
The **signs and symptoms** of fracture of the shaft of the humerus consist of pain and swelling, with ecchymosis at the seat of fracture, crepitus, false point of motion, shortening of the arm, and complete loss of function.

The **treatment** of fracture of the shaft of the humerus depends upon the special seat of the fracture. As a general rule, the best dressing, if there is only slight displacement, is a bandage of plaster of Paris applied over a layer of absorbent cotton. The bandage must include the flexed forearm as well as the arm, and then form a spica over the shoulder. In case the fracture is attended with much shortening, and extension seems necessary, the short internal and the long external splint (Fig. 105), made of leather or gutta-percha or pasteboard, can be fitted and moulded to the opposite arm, and then adjusted to the broken one. Usually the weight of the arm below the fracture, together with the forearm, afford sufficient extension when the hand is swung in a sling. Great care should be exercised lest the internal splint cause compression of the axillary vessels.

FIG. 105.

Physick's elbow-splint.

FIG. 106.



Clark's extension in fracture of the neck of the humerus.

In special cases, requiring greater extension to overcome the deformity and to maintain the apposition, the surgeon can employ an extension apparatus by means of adhesive plaster applied from the upper end of the lower fragment to the elbow-joint, and from the cross-piece below the joint attach a bag of sand, as suggested by Clark (Fig. 106). The patient can be up and walk about during the repair of the fracture, or, if for any reason he is obliged to remain in bed, a weight and pulley can be used as in fracture of the tibia. The weight, however, must be accurately adjusted to the existing conditions, since too great weight might

separate the fragments and cause non-union of the fracture, a not uncommon complication in fractures of the humerus. Where the upper fragment shows a tendency to become abducted with a slight forward inclination, a splint in the form of a triangle has been suggested, but its employment is attended with much difficulty.

In fractures of the shaft there is danger of non-union, and also some danger of gangrene of the fingers from too tight bandaging or from too great axillary compression if splints or pads are employed. If the radial artery cannot be felt at the wrist, no bandage or splint should be employed, since its application might be considered as the cause of gangrene. There is also an additional danger of subsequent paralysis of the muscles presiding over supination of the forearm and extension of the hand and fingers, causing pronation of the hand and wrist-drop. This may occur as a result of injury to the musculo-spiral nerve (Fig. 107), or in consequence of an exuberant callus which ensheaths and compresses the nerve (Fig. 108). In the latter case the nerve can be tunnelled out after the fracture is repaired (Fig. 109), or in some cases the two ends of the divided nerve may be found and sutured. In fractures of the humerus Stromeyer's cushion (Fig. 110) is often of great service if for any reason the fracture cannot be placed permanently in a retentive apparatus.

FIG. 107.

Paralysis of hand (wrist-drop) after fracture of humerus.

Fractures of the Upper End of the Humerus.—Epiphyseal separation is usually the result of direct violence, as a fall or blow upon the shoulder. This injury is not observed after the twentieth year of life.

The **signs and symptoms** are a prominence below the coracoid process, due to the upper end of the lower fragment, which projects in front of the shoulder-joint; slight crepitus, which is obtained by rotation of the shaft of the humerus (Fig. 111); the alteration in the axis of the shaft, which above is drawn inward by the action of the anterior pectoral muscles, and is directed downward and slightly backward and outward (Fig. 112); the head of the bone is felt in the glenoid cavity, but does not move with the shaft during rotation; ecchymosis, tenderness, and pain are well marked.

FIG. 108.

Permanent flexure from paralysis after fracture of the humerus.

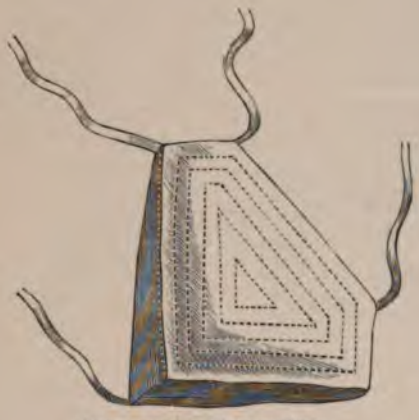
FIG. 109.

Apparatus for wrist-drop after fracture of the humerus.

The **treatment** consists in making extension upon the shaft of the bone until the projection in front of the joint disappears. At the same

time the thumb of the surgeon should push back the upper edge of the lower fragment into its proper place. The elbow-joint should be carried inward to the side of the thorax. Compresses and pads should be placed

FIG. 110.



Stromeyer's axillary cushion.

over the front of the joint, and they should be held in place by a felt shoulder-cap or a leather cap, applied wet and accurately moulded to the sound shoulder. Care should be exercised lest any undue pressure

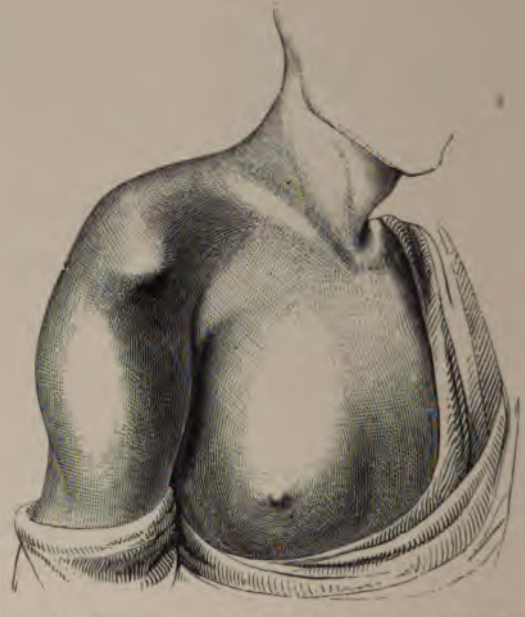
FIG. 111.

Separation of the upper epiphysis of the humerus; displacement forward of the lower fragment.

upon the front of the joint result in a slough. Some slight deformity may exist after repair of this injury, but the movements of the shoulder-joint are not much interfered with, since the separation is outside of the capsule.

Fracture of the tuberosity of the shaft occurs as a result of direct violence. The antero-posterior diameter of the joint is increased, and there is a sulcus found between the front of the joint and the fragment, which

FIG. 112.



Separation of the upper epiphysis of the humerus (R. W. Smith).

is drawn upward and abducted by the external rotators, giving the shoulder a peculiar contour, described by some authors as trumpet-shaped, on account of the double tumor, one under the acromion, and the other under the coracoid process. There is a well-marked depression just beneath the acromion process, and crepitus is easily obtained by rotation of the shaft with the fingers holding the separated tuberosity. The rotation of the humerus shows no impairment in the movement of the head of the bone in the glenoid cavity.

The **treatment** of fracture of the tuberosity consists in making the shaft of the bone adapt itself to the detached tuberosity. This is best accomplished by a pad in the axilla, which throws the upper end of the bone outward. The elbow should be brought to the side of the chest-wall and the forearm suspended in a sling. A pad should be placed behind and above the tubercle after it is reduced, so as to prevent it from slipping upward and backward by the action of the rotators attached to the fragment.

Fracture of the surgical neck is situated outside of the capsule of the joint, and corresponds to the extra-capsular fracture of the cervix femoris. The line of fracture is below the tuberosities, but above the insertion (Fig. 113) of the pectoralis major, latissimus dorsi, teres major, and deltoid muscles.

The displacement consists of an external rotation and abduction of the upper fragment, caused by the action of the muscles inserted into the greater tuberosity—viz. the supra-spinatus, the infra-spinatus, and the teres minor muscles—while the shaft of the bone is drawn upward into the axilla by the action of two of the three muscles which take their origin from the coracoid process —viz. the biceps and the coraco-brachialis muscles—and inward by the action of the pectoralis major and the teres major muscles.

FIG. 113.

Fracture of the surgical neck of the humerus.

The **signs and symptoms** are—absence of rotation of the head of the bone with the shaft, while at the same time the head of the bone remains in the glenoid cavity; shortening of the arm to the extent of about one inch; crepitus, unless the fracture is impacted; swelling, pain, and ecchymosis; alteration in the axis of the bone, which is directed downward and outward; and a peculiar flattening of the shoulder just below the acromion. This flattening is not so marked as in dislocation, but more so than in fracture of the anatomical neck.

The **treatment** consists in the application of a plaster-of-Paris bandage, which includes coaptation splints to the broken arm and a spica over the shoulder, with the forearm flexed to a right angle, and the employment of the axillary pad. In case the fracture is attended with much deformity, a splint in the form of a triangle has been employed with great success, since the apparatus makes the shaft adjust itself to the upper fragment. If it is unnecessary to employ the triangle, the elbow should be carried well forward and brought close to the side of the body; which position has a tendency to overcome the inward displacement of the shaft.

Fracture of the anatomical neck is produced by direct violence, as in a gunshot wound or by a fall upon the shoulder. The fracture is within the capsule of the joint, and corresponds to the intra-capsular fracture of the cervix femoris. The fragment receives no blood-supply, and is prone to undergo necrosis and to establish suppuration in the joint. Union may result if impaction is present, and for this reason any attempt roughly to manipulate the fracture with a view to a diagnosis may be attended with serious results.

The displacement is very slight, if any, owing to the peculiar anatomical conditions.

The **signs and symptoms** consist of a prominence of the acromion and flattening of the shoulder, both of which, however, exist only to a moderate degree; shortening of the arm to the extent of about half an inch, with pain, swelling, and crepitus, unless the fracture is impacted; and absence of ecchymosis, since the fracture is within the capsule.

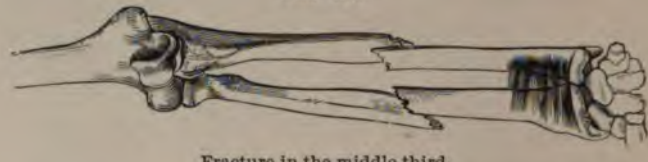
The **treatment** consists in the application of evaporating lotions for a few days to control the inflammation in the joint, and afterward in the adjustment of a felt or plaster-of-Paris shoulder-cap and a pad in the

axilla. Great care should be exercised lest the surgeon break up the impaction and thus prevent union of the fragments.

FRACTURES OF THE FOREARM may be divided into fracture of the coronoid or olecranon process of the ulna, of the shaft of the ulna, of the styloid process of the ulna, of the head and neck of the radius, of the shaft of the radius, of the lower end of the radius (Colles), and of both radius and ulna.

Fractures of the radius and ulna usually occur as the result of direct, but they may be caused by indirect, violence. The seat of the fracture is usually about the centre of the shaft of each bone (Fig. 114). If by direct violence, the fracture may occur at any place, but generally at

FIG. 114.



Fracture in the middle third.

the lower end, since this part is more exposed to injury, and is less protected by a cushion of muscles.

The displacement varies according to the situation and line of fracture. The bones may be so displaced as to form an angle either in front or behind, or even laterally. In some cases the fragments overlap, so as to cause great shortening of the forearm.

The **signs and symptoms** of fractures of the radius and ulna are those which are ordinarily found in any fracture, such as crepitus, loss of function of limb, great pain and tenderness, unusual mobility, ecchymosis, and swelling.

The **treatment** consists in reducing the fracture by the surgeon making extension with the patient's fingers flexed and grasping the entire hand, while counter-extension is made by an assistant, who seizes the elbow-joint while the forearm is flexed. If the fracture is below the insertion of the pronator radii teres, two lateral splints should be applied, and the forearm placed midway between pronation and supination. The

FIG. 115.

Fusion of bones after fracture of radius, destroying pronation and supination.

splints should be wider than the forearm, so that the bandage or strips of adhesive plaster will not press the bones together and cause fusion of the bones, which would destroy the function of pronation and supination (Fig. 115). If there is any tendency of the lower fragments to drop, the

lateral splints should extend below, so as to support and include the hand. If the fracture is above the insertion of the pronator radii teres, the forearm should be strongly supinated and a posterior angular splint applied (Fig. 116).

An excellent method of treating this fracture, if the individual will submit, is for the patient to lie in bed, and then to extend the arm and

FIG. 116.

Dr. Scott's splint for fracture of the forearm.

forearm upon a long flat, firm cushion. This position brings the fragments into accurate apposition. In treating any fracture of the forearm in the flexed position with splints great care must be exercised lest the splints should cause undue pressure and produce gangrene of the fingers. The pressure of the splints and the flexed position of the forearm necessarily retard the free flow of blood through the vessels, and for this reason the possibility of gangrene must be always borne in mind.

Fracture of the lower end of the radius is known as Colles's fracture, after the renowned Irish surgeon who first described the nature of this injury. The seat of the fracture is about one inch above the articulation, at the junction of the compact with the cancellated bony tissue. This fracture has also been called the "silver-fork fracture," because the characteristic deformity resembles the shape of an ordinary silver fork. The dorsal prominence is due to the riding upward and backward of the lower fragment with the carpus, while the palmar deformity is produced by a projection forward of the lower end of the upper fragment, which is pronated by the action of the pronator quadratus and pronator radii teres muscles. The internal lateral ligament is generally torn out of its insertion into the styloid process, and Moore has demonstrated that the process becomes entangled in the annular ligament. The lower end of the upper fragment is generally driven into the upper end of the lower fragment by the continuance of the same force that originally caused the fracture. This impaction of the upper fragment, consisting of compact bony tissue, into the lower fragment, formed of cancellated tissue, explains the frequent absence of crepitus in the fracture (Fig. 117).

The **signs and symptoms** of fracture of the lower end of the radius are—inability to support the forearm, the position of the hand midway

between pronation and supination, the flexion of the fingers, the silver-fork deformity, the great prominence of the styloid process of the ulna,

FIG. 117.

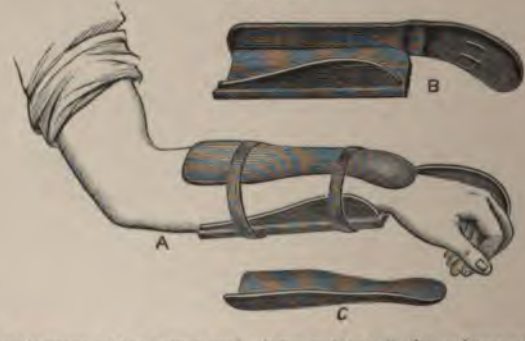
Colles's fracture: union with persistence of displacement (Smith).

the loss of supination and pronation, severe pain, and often swelling due to effusion into the sheaths of the tendon.

The **treatment** of this fracture consists in overcoming at once the deformity by promptly reducing the fracture and then retaining the fragments immovably fixed in their proper position. The reduction is made by the surgeon grasping the hand of the patient as if to shake hands with him, and then making forcible continuous and gradual extension, so as to disengage the impaction and bring the lower fragment into apposition with the upper. The surgeon should place the thumb of the left hand against the styloid process of the ulna and push it around, so as to bring it into its normal position. In some cases it may be necessary to administer an anæsthetic in order to reduce satisfactorily the deformity. The fixation of the adjusted fragments can be maintained by several different forms of splints.

The best dressing is by two lateral splints, which should be well padded and broad, and extend from the extreme upper end of the forearm to exactly the lower margin of the lower fragment, and leave the wrist-joint free. The forearm should then be placed in a sling, so that the hand falls downward and is adducted by its own weight, in which

FIG 118.



Gordon's splint for fracture of the lower end of the radius: *B*, the palmar splint; *C*, the dorsal splint; *A*, the two splints applied to the forearm.

position the torn ligament from the styloid fossa is relaxed and the fragment of the radius is brought into accurate apposition. This freedom

of motion of the wrist-joint does not interfere with the complete fixation of the fragments, and prevents ankylosis of the joint, as well as any subsequent rigidity of the fingers.

Gordon's apparatus consists of two pieces, a palmar splint (Fig. 118) constructed so as to overcome the forward displacement of the fragment by the addition of a conical piece, which produces pressure upon the lower end of the upper fragment, and thus has a tendency to elevate it, while the hand itself raises the lower fragment. The other splint is applied to the dorsal surface of the forearm, and by its thick padding over the wrist has a tendency to overcome the deformity.

Carr's apparatus (Fig. 119) consists of a palmar splint padded so as to obliterate the depression over the radius. To the extremity of this

FIG. 119.

Carr's splint for a left Colles fracture.

palmar splint is attached an oblique vertical piece, and on this round bar the fingers are flexed. This palmar splint is supplemented by a second or dorsal splint.

Bond's apparatus (Fig. 120) consists of a splint made of a piece of wood, to the lower extremity of which is fixed a curved block which

FIG. 120.

Bond's splint.

should fit the hollow of the palm in order to give support to the hand and fingers. The splint should be well padded, so as to fill up the convexity of the radius on its palmar side. In conjunction with the palmar splint a dorsal splint is used, with a compress so adjusted as to effect the reduction of the lower fragment.

A fracture consisting of a chipping off of the posterior lip of the articulating surface of the radius has been described by Barton, after whom the fracture is named. The fracture clinically requires the same treatment as that indicated for Colles's fracture.

Fracture of the shaft of the radius occurs by direct violence, as a blow upon the forearm, or by indirect violence, as a fall upon the hand. As a rule, however, a fracture of the radius caused by a fall upon the

hand is situated in the lower end, but occasionally this injury causes a fracture of the shaft of the bone.

The displacement in fractures of the shaft depends upon the situation of the fracture, since the deformity varies according to whether the fracture is above or below the insertion of the pronator radii teres muscle. If the fracture is above the insertion of this muscle and below that of the biceps, the upper fragment is strongly supinated and flexed, while the lower fragment is pronated by the pronator radii teres and the pronator quadratus. This displacement is not very apparent, on account of the anatomical conditions; but if union takes place without correction of the deformity, fusion of the bones occurs and the movements of pronation and supination are lost; and this movement can only partially be accomplished by the shoulder. If the fracture is situated below the insertion of the pronator radii teres, this muscle opposes the action of the biceps and the supinator brevis, so that the forearm remains in a position midway between pronation and supination (Fig. 121). The supinator longus below opposes the feeble action of the pronator quadratus. The displacement consists of slight flexion of the upper fragment by the biceps and pronation by the pronator radii teres, and a drawing inward of the lower fragment by the pronator quadratus, assisted by the supinator longus, which by traction of the lower end of the lower fragment tilts the upper end of the lower fragment toward the ulna.

FIG. 121.

Fracture of the radius.

The **signs and symptoms** of fracture of the shaft of the radius are those usually found in any fracture, such as pain; false point of motion; and crepitus, which in this special fracture is elicited by rotating the hand while the surgeon places his thumb on the head of the radius, or by indentation of the two broken ends at the seat of fracture.

The **treatment** varies according to the seat of the fracture. From a careful study of the displacement when the fracture is above the insertion of the pronator radii teres, it is evident that the forearm must be strongly supinated in order to bring the fragments into accurate apposition. For this purpose it is necessary strongly to supinate the forearm. This can be done by placing the patient in bed and stretching his arm out at a right angle from the trunk, and allowing the supinated arm to rest upon a hard cushion; or, if the patient is unwilling to be confined to the bed, the forearm can be flexed to a right angle with the arm, and a splint applied to the arm and forearm (Fig. 122), so that the palm is directed upward. If the fracture is below the insertion of the pronator radii teres, the application of two lateral splints can be made, with the forearm midway between pronation and supination. Some surgeons recommend that the splint extend only to the wrist-joint, but if there is much mobility it may be well to have the splint extend below and support the hand, since there is no tendency for the wrist-joint to become

ankylosed. A small strip or pad down the centre of the splint has been suggested, so as to separate the radius and ulna to prevent any union

FIG. 122.

Dr. Scott's splint for fracture of the forearm.

of the two bones, which would impair the movements of pronation and supination.

Fracture of the head and neck of the radius rarely occurs, except in connection with a dislocation backward of both bones of the forearm or with a fracture of the coronoid process of the ulna. The fracture may be, however, occasionally observed as the result of a gunshot injury, or it may be present in the form of a compound fracture, in which case the head and neck are usually splintered in the long axis of the bone (Fig. 123). It is sometimes found to be comminuted.

FIG. 123.

Fracture of neck of radius.

The **signs and symptoms** are inability to pronate or supinate the forearm; crepitus at the seat of fracture, elicited by seizing the patient's hand and pronating the forearm while the thumb of the surgeon's other hand is placed over the orbicular ligament; the presence of an unnatural bony prominence at the insertion of the biceps, due to the flexion and supination of the fragment by the action of this muscle; the presence of ecchymosis and localized pain; and the peculiar position of the forearm, which is pronated.

The **treatment** consists in placing the forearm in a position of extreme flexion, which relaxes the biceps, which tilts forward the fragment. A compress should be applied to the fragment in order to keep it in position, and the limb bandaged to an angular splint. Care must be taken not to produce any compression upon the brachial artery while the forearm is extremely flexed, lest the circulation be disturbed and gangrene ensue. Passive motion must not be practised until the fragment is well united, lest the biceps, contracting during forced extension, might separate the fragment. If there is great tend-

ency for the fragment to become flexed and supinated by a rigid contraction of the biceps, tenotomy will immediately overcome the deformity, and the parts will be at once adjusted.

Fracture of the styloid process of the ulna occurs as a result of direct violence. The fragment is distinctly felt just beneath the skin.

The **signs and symptoms** are too apparent to require any special description. The broken fragment should be manipulated until it is brought into its proper position, and then maintained there by the use of a compress which is held firmly *in situ* by strips of rubber plaster. It is advisable to keep the wrist- and elbow-joints at rest for a short time until the fragment unites, as any movement of these joints has a tendency to displace the broken part.

Fracture of the shaft of the ulna occurs as a result of a fall, or in boxing, in warding off blows aimed at the face, and its seat is usually just below the middle of the bone, since at this point the bone is not so thick and is less protected by a cushion of muscles.

The displacement is caused by the action of two muscles—viz. the brachialis anticus, which has a tendency to flex the upper fragment, and the pronator quadratus, which has a tendency to abduct it and thus draw it toward the radius.

The **signs and symptoms** are localized pain, tenderness, and ecchymosis, the presence of a tumor, the existence of crepitus and great mobility. The finger, if passed along the shaft of the bone, will usually detect the fracture, as the bone is quite superficial in the lower half of the shaft.

The **treatment** consists in the application of two broad lateral splints from the elbow- to the wrist-joint. Before adjusting the splints the broken ulna should be forced away from the radius, so as to prevent any fusion of the bones of the forearm, which would impair pronation and supination. The forearm should be flexed at a right angle in order to relax the brachialis anticus, which has a tendency to tilt forward the upper fragment, and also be placed midway between pronation and supination. The forearm should be carried in a sling, and the lateral splints should be broad enough to prevent any pressure upon the broken bone, which pressure would have a tendency to cause fusion of the two bones of the forearm.

Fracture of the coronoid and olecranon processes of the ulna occurs as a result of a fall upon the back of the elbow during semi-flexion of the forearm, or by muscular action. Fracture of either process is seldom seen in a person under fifteen years of age.

Fracture of the coronoid process usually occurs as a complication backward dislocation of both bones of the forearm, which accident usually the result of a fall upon the palm with the elbow-joint partially flexed. The fracture has been observed as a result of muscular action in attempts to lift the weight of the body with the hand or in grasping by the hands an object in the act of falling from a height.

The **signs and symptoms** are backward dislocation of both bones of the forearm, the presence of crepitus, the existence of a bony prominence in the transverse fold of the elbow-joint, and a tendency to return of the deformity after reduction.

The **treatment** consists in placing the forearm in an extreme

flexed position to relax the brachialis anticus muscle, and applying an angular splint with an angle adapted to the position. If the fragment persists in becoming displaced, it can be wired to the shaft. In such an operation the close proximity of the brachial artery must not be overlooked. Unless the fragment is sutured, the union is likely to be ligamentous, and passive motion should be instituted after three weeks in order to preserve the mobility of the joint.

Fracture of the olecranon process of the ulna occurs during adult life and seldom before the fifteenth year. The fracture is the result of direct violence, either from a blow upon the process or by a fall upon the part when the elbow-joint is flexed to a right angle. This fracture also occurs by muscular action, as in sudden contraction of the triceps during extension of the forearm. The mechanism of fracture by this cause is that of a lever across the condyles of the humerus.

The **signs and symptoms** are—well-marked depression at the back of the elbow-joint, produced by the action of the triceps in drawing upward the fragment; the presence of crepitus, elicited by flexing and extending the forearm; abnormal mobility of the fragment; the existence of synovitis of the elbow-joint; the stationary appearance of the fragments; and the separation of the shaft of the ulna from it during extension.

The **treatment** consists in placing a compress over the fragment after it has been reduced, and applying a strip of adhesive plaster to keep the fragment immovably fixed to the shaft of the ulna. A straight splint which is well padded should now be adjusted to the arm and forearm upon their anterior surface, with the limb in an extended position. If the fragment cannot be kept in place, suturing it to the shaft is indicated. This operation must be done with every aseptic precaution, since the wound communicates with the joint. If the fracture is compound, suturing is indicated, and at the same time free drainage of the joint for a few days must be employed. If for special reasons suturing is not advisable and a stiff joint is likely to ensue, the forearm should be placed midway between flexion and extension, since this position renders the upper extremity more serviceable than the straight position, which gives the patient practically a useless arm.

FRACTURE OF THE CARPAL BONES is rare, and occurs, as a rule, from direct violence. Owing to the strong ligaments which hold the carpal bones together, there is little displacement. Fractures of these bones are often overlooked on account of the extensive damage of the soft parts and the consequent swelling of the wrist-joint. There is very little displacement, owing to the anatomical arrangement of the wrist articulation.

The **signs and symptoms** are crepitus, swelling, pain, and loss of function of the joint.

The **treatment** consists in placing the hand upon a long palmar splint, at the same time applying over the injured part warm fomentations or cold evaporating lotions until the acute inflammation has subsided. In severe contusion of the soft parts without wound the warm applications are best suited, while in severe inflammatory reaction unaccompanied by external wound the cold lotion is indicated. Absolute rest, a moderate amount of compression, and an immovable splint to give

support to the hand, wrist, and forearm are required. When the signs of acute inflammation have disappeared, a splint should be applied, and passive motion begun after a fortnight in order to preserve the motion of the joint. If the fracture is compound, the loose fragment must be removed, the joint thoroughly irrigated, and a drainage-tube passed through from the dorsal to the palmar surface, and antiseptic dressings applied together with a splint.

Fractures of the metacarpal bones are common, and are usually the result of direct violence. On account of the exposed position of the first metacarpal bone, it is found to be the one most frequently fractured, and after it, next in point of frequency, the second, while the third is less frequently broken than the others. The upper fragment is usually displaced downward toward the palm of the hand, owing to the action of the interosseous muscle and the natural shape of the shaft of the bone.

The **signs and symptoms** consist of crepitus, pain, swelling, interruption of the continuity of the shaft of the bone, prominence in the palm of the hand due to the presence of the distal end of the proximal fragment, the dropping of the knuckle, and the depression on the dorsum due to the falling down of the two fragments.

The **treatment** consists in placing the hand upon a long palmar splint extending from the elbow to a point beyond the fingers, with a pad over the seat of fracture on the palmar surface of the hand, or by flexing the hand over a ball, so as to push up the displaced fragments by mechanical action and by extension of the fragments, and at the same time applying the long splint.

Too much importance cannot be attached to the conservative treatment of compound fractures of these bones. The parts are so vascular, and the reduction of the fragments so easy, that it seldom becomes necessary to perform amputation if proper antiseptic precautions are employed. The fragments should be wired if greatly displaced, or some of the comminuted pieces should be removed and the periosteum left, or even transplantation of the bones can be accomplished when the necessary conditions are present. In Figure 124 is shown the result obtained in a case of a compound, comminuted, and complicated fracture of the second metacarpal bone and the two phalanges of the thumb. As the two phalanges of the thumb were spontaneously amputated by machinery at the time of the accident, the metacarpal bone of the thumb, which was not injured, was transplanted and attached to the proximal end of the first phalanx of the index finger, which was also uninjured. The metacarpal bone belonging to that finger was comminuted, and its pieces forced out of the hand, so that its place was now occupied by the first metacarpal bone of the thumb. The result of the operation was most gratifying, since the patient had a most useful hand, which was superior to any artificial one. The operation was performed in my hospital service by Dr. Rau, the house-surgeon.

Avulsion of the phalanges requires consideration. This accident occurs where the finger is held in a door of a stage or car, or where the finger is caught upon some object while the patient is running. The entire phalanx is torn away from its nearest articulation, and with it the tendon of the muscle which is inserted into it. Avulsion of the thumb,

with the tendon of the flexor longus pollicis, has occurred in violent attempts to reduce a dislocation of the thumb, a beautiful example of

FIG. 124.

Amputation of first and second phalanges of the thumb, and excision of the metacarpal bone of index finger: transplantation of metacarpal bone of the thumb to the index finger.

which, as well as of similar results from other causes, is seen in the accompanying plate (Fig. 125).

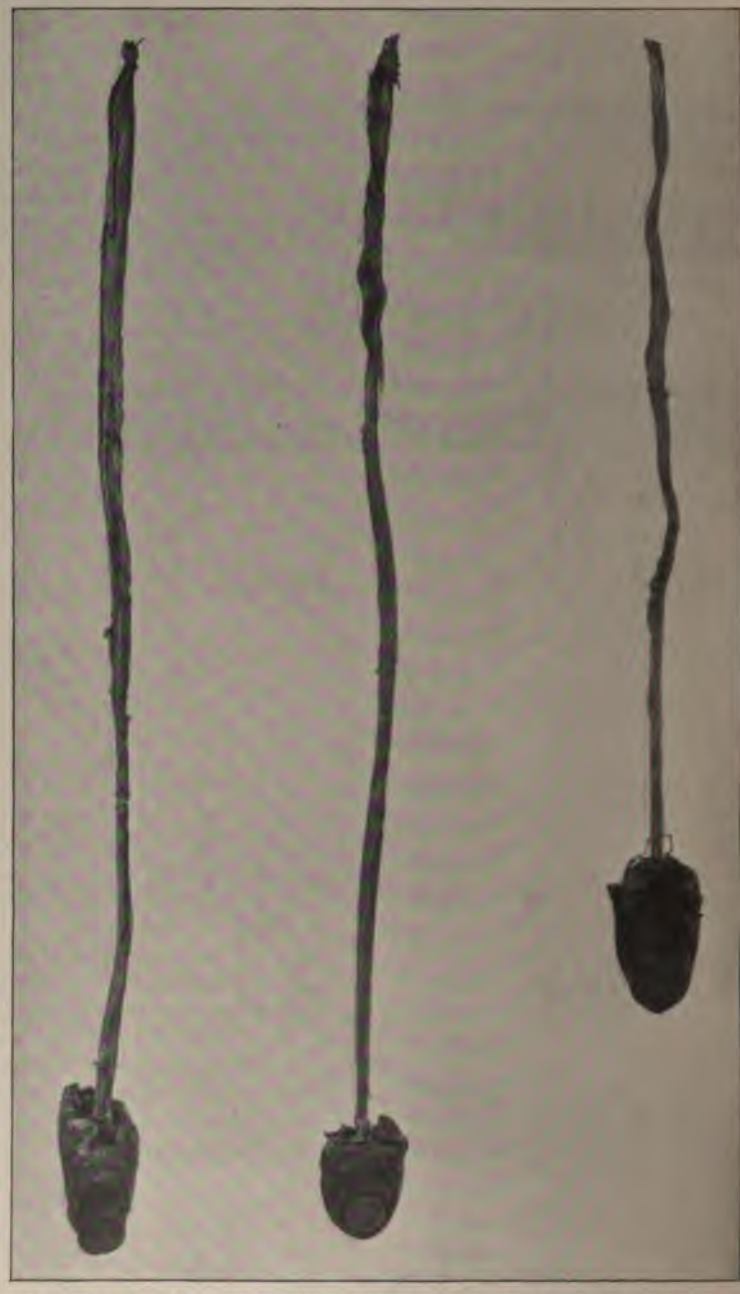
The **treatment** of simple fractures of the phalanx consists in restoring the fragments to their proper place and holding them *in sitû* by means of a gutta-percha, pasteboard, metal, or leather splint, accurately moulded to the corresponding finger of the opposite hand, and then applied to the injured and extended phalanx. In addition to a splint directly applied to the fractured part, a long splint should extend from the palm of the hand to the tip of the finger, so as to keep the fragments immovably quiet during the repair of the fracture. If the fracture is compound and comminuted, the surgeon should endeavor to save as much as possible, and remove only pieces which are detached from the periosteum, since the reparative process is so great that a fracture in this part would repair where elsewhere the bone might undergo necrosis.

Fracture of the phalanges occurs as a result of direct violence, and on account of the exposed position of the hand is frequently observed. The important fact must always be borne in mind that while an artificial limb can be substituted for the arm or forearm, the leg or thigh, no prosthetic apparatus has been devised to take the place of the finger. For this reason it is imperative for the surgeon to apply the principles of extreme conservatism in the management of fractures of the phalanges, and in carrying out this principle too much importance cannot be placed on the great vascularity of the parts and their tendency to heal even after the most extensive injury.

DISLOCATIONS.

A *dislocation* is a solution in the contiguity of bones, and is in contrast to a fracture, which is a solution in the continuity of a bone. A *diastasis* is where the bones are separated from each other, as when the pubic bones separate at the symphysis pubis. The term "disloca-

FIG. 125.



Specimens showing avulsion of the distal phalanges in attempts to reduce a dislocation of the thumb, the result of an accident.

tion" is derived from the Latin preposition *dis*, meaning a separation, and the noun *locus*, denoting a place.

Dislocations are less frequent than fractures in about the proportion of 1 to 8. A *simple* dislocation is one in which the joint is displaced without concomitant injury to vessels, nerves, or bones. A *compound* dislocation occurs when the displacement is of such a character as to open the joint and expose it to the external air. A dislocation is *complicated* when the displacement is associated with a laceration of the vessels or nerves or a fracture coexists. A *complete* dislocation is one in which the joint-surfaces are entirely separated. An *incomplete* dislocation is one in which the joint-surfaces are only partially separated. From a study of Gurlt's, Krönlein's, and Prahl's tables it is demonstrated that dislocations of the upper extremity form nearly three-fourths of all dislocations, that the shoulder is the most frequently dislocated joint in the body, and the elbow next, while in the remaining one-fourth dislocations of the fingers and the hip are in the majority. In regard to sex, it is also proven that dislocations are three times more frequent in males, with the exception of the jaw, where the proportion is more than

FIG. 126.

FIG. 127.

Congenital dislocation of hip.

reversed. As regards age, it is demonstrated that between the ages of fifty and sixty dislocations are most frequent, and that dislocations

are less frequent during the years when fractures are most common, especially during infancy and youth.

There are three distinct varieties of dislocations—the *congenital*, the *pathological*, and the *traumatic*.

A *congenital* dislocation is one in which the joint-surfaces do not fit, owing to arrest of development in the fœtus or to some malformation of the parts, as in the different varieties of club-foot, torticollis, or spinal curvature. This variety occurs in 87 per cent. of the cases in females, and affects generally the hip-joint (Fig. 126). It may also occur as a result of abnormal uterine contraction, or of falls upon the abdomen during pregnancy, or of some violence during obstetrical manipulation in a case of difficult labor. Congenital dislocation may also result from disturbance of the nervous centres, as in spastic contractions of the muscles, in infantile paralysis, and in pseudo-hypertrophy. A congenital dislocation is not always recognized at the time of birth, and often not until the child makes attempts to walk. The hip, shoulder, knee, ankle, patella, tarsus, and phalanges are among the joints and bones that are most frequently the seat of this special variety of dislocation.

The *pathological* dislocation, as its name implies, is one produced as the result of disease. This variety is seen during the progress of morbus coxarius, and also in chronic disease of the knee-, ankle-, and other joints. The joint disease produces absorption of the head of the bone with destruction of the capsule, and the entire cavity and the head of the bone become more or less obliterated (Fig. 128). Another variety may occur as a result of reflex muscular contraction from disease of the spinal cord, and in this variety a distinction must be made from the preceding pathological dislocation, since the joint itself is not the seat of bone disease. This same variety may also occur in the course of certain fevers, as typhoid, or articular rheumatism: suddenly the joint, usually the hip, becomes dislocated, the capsule having ruptured from over-distention.

FIG. 128.

Pathological dislocation of the hip-joint.

The *traumatic* dislocation, which is due to external violence, may occur in almost any joint in the body. The injury may result in either a complete or an incomplete luxation of the joint, the special form of which depends upon the amount of violence exercised, together with the peculiar anatomical conformation of the joint. Krönlein has demonstrated that about 90 per cent. of the traumatic dislocations affect the upper extremity, while only about 5 per cent. involve the lower extremity, and the remaining affect the trunk. The ages between twenty and forty are the periods when traumatic dislocations are most frequently observed.

The **pathology** of dislocation involves much more than the mere luxation of the joint, since in every case the injury not only affects the articulating surfaces, but in addition the ligaments are torn, the muscles are lacerated, the cartilages are contused, the arteries are ruptured, the nerves are stretched, and the fascia embracing the joint is torn away from its attachment. In compound dislocation the skin is broken and usually destroyed, while the larger vessels are often torn. It is thus evident that a dislocation is a serious injury, and if it happens to affect a large joint and is compound in character, it involves life itself, and in all cases affects to a greater or less degree the future usefulness of the joint. In gouty, syphilitic, tubercular, or rheumatic persons a dislocation of a joint is often the starting-point of a chronic suppurative arthritis, which assumes a peculiar type according to the diathesis, and leads eventually to resection of the joint or even amputation of the limb.

In dislocation of the shoulder, occasionally, the branches of the axillary, or even the axillary itself, are wounded, either by rupture of the middle and internal coats or by rupture of the three coats simultaneously. If the former has occurred, an aneurism slowly develops, while if the latter has occurred, a rapidly-growing traumatic aneurism develops, with signs of collapse and gangrene of the extremity. This same condition may obtain in reference to the popliteal vessels in dislocations of the knee. The management of such anomalous cases includes reduction of the dislocation and an operation for the immediate relief of the hæmatoma. This latter operation is to be performed according to the rules governing the methods of treatment discussed under Aneurism.

Large nerve-trunks may be injured as a result of a dislocation. The paralysis may be due to pressure owing to the presence of blood or bone. This disturbance of function in the nerve disappears after absorption of the extravasated blood and removal of the bone-pressure. The paralysis may be due to laceration of the nerve, which condition is not likely to disappear, or it may be caused by injury during attempts to reduce a dislocation. A neuritis, or even traumatism of the nerve-trunk, may cause a paralysis, and this condition result from the same injury that produced the dislocation. In investigating a dislocation the possibility of injury to internal organs must not be overlooked. The pelvic organs in dislocation of the hip, and the œsophagus in dislocations of the clavicle, are often the seat of injury which leads to disturbance of function or destruction of the organ or viscus.

In considering the **signs** of dislocation it is not inappropriate to compare this injury with fracture, which is usually a less serious accident. In dislocation the shaft of the bone belonging to the affected joint is not shortened, though the entire limb may be shortened. In dislocation there is absence of mobility, and hence the false point of motion, which is so characteristic of fracture, is absent in dislocation. There is no tendency for a dislocation to return after reduction unless further violence is exerted, while the deformity is likely at once to reappear in a fracture left to itself. In dislocation there is often present a kind of crepitus which must not be mistaken for that of fracture. The crepitus found in dislocations is of a peculiar kind, and is not bony unless a fracture coexists: it is due to blood-clots, lymph, or albumin, and in some cases to a roughening of joint-surfaces.

In *unreduced* dislocation the result varies according to the point involved and the extent of the injury. In the hip and ankle and the shoulder and elbow changes occur through the efforts of Nature, by means of which often a most serviceable joint is constructed. The connective tissue undergoes a certain amount of condensation, and mechanically prevents the head of the displaced bone from farther receding from its new position. The active use of the new joint causes a certain amount of absorption of bone, and makes the globular head move with comparative freedom in its newly-made socket. The irritation set up causes proliferation of the connective tissue, which is soon transformed into fibrous tissue, and around the head of the bone a complete wall is thus formed, the inner side of which is lined by flat cells which secrete a small amount of fluid, which in turn serves to lubricate the new joint-socket. Often some part of the synovial membrane is torn away, and if nourished continues to secrete some synovia. The changes which occur in the bone and its coverings are of interest to the pathologist, since the periosteum often produces bone and the fibrous tissue undergoes ossification. The pressure of the head of the bone on the periosteum, which is not detached from the bone, causes it to inflame from continual irritation, and thus new bone is developed to aid in the formation of a bony cavity for the reception of the displaced head. During these changes the original joint-socket becomes gradually obliterated by a process of absorption and by the development of granulation tissue in the bottom of the cavity. A study of all of these changes in the new socket, in the head of the bone, and in the original joint-cavity, with the blood-vessels and nerves imbedded in the newly-formed inflammatory tissue, teaches the important lesson that the surgeon must not overlook the danger of attempting by violence to reduce old dislocations, since the risk of tearing vessels and nerves, and even of causing a fatal issue, is imminent.

The **causes** of dislocation may be divided into *predisposing* and *exciting*. Among the predisposing causes may be mentioned unusual freedom of movement in a joint, the male sex, the adult age of the patient, the arrest of joint-development, and senile or pathological absorption of the head of the bone with changes in the joint-cavity. Among the exciting causes may be mentioned mechanical violence and muscular action.

The **signs and symptoms** of dislocation are—disturbance of function of the joint, interference with passive motion, sudden loss of motion, absence of the natural contour of the joint, changes in the relation of the muscles about the joint, alteration in the shape of the limb, pain, tenderness, and ecchymosis. Immobility is present, with no shortening in the shaft of the bone, although there may be shortening of the entire limb.

The **subsequent effects** of dislocation vary according to the special joint involved and to the amount of violence exercised at the time of the receipt of the injury. The future usefulness of the joint depends upon the degree of success attained in the reduction. If the dislocation is simple and is quickly reduced, beyond the fact of a slight tendency to a redislocation no bad effects may ensue. In certain cases paralysis of the limb may follow, owing to a concomitant injury of the nerves. If, on the other hand, the dislocation is compound, amputation or resection may be required.

The **general treatment** of simple dislocations consists in the immediate reduction and fixation of the joint. There are, however, certain causes which prevent reduction, such as intervention of soft parts; too small tear in the capsule or too rapid healing of the capsule; absorption of the joint-cavity; and, finally, obliteration of the cavity by granulation tissue. In considering the subject of reduction there are certain dangers which must not be overlooked, such as fracture of the bone, tearing important vessels like the subclavian, and even complete avulsion of the limb, especially when Jarvis's adjuster is employed under the influence of anæsthetics.

The question as to how long a dislocation can exist and yet be reduced is one which interests the surgeon in connection with the general principles involved in the treatment of this injury. There are reported cases where the wrist has been dislocated for six years, the shoulder for two years, and the hip for nearly three months, and yet these dislocations have been reduced, but they are surgical curiosities. As a rule, after a fortnight it is extremely difficult to reduce a dislocation. In these days, however, a resection can be made and a useful joint obtained, even though the dislocation has existed indefinitely.

In case a fracture coexists with a dislocation, the reduction of the dislocation should precede the treatment of the fracture, and in all cases in which shock is present the surgeon should avail himself of this condition to reduce the dislocation. In cases where shock is extreme a short delay may be necessary in order to adopt measures to bring about reaction.

The treatment of congenital dislocation is chiefly palliative, since the absence of a fully-developed joint makes it impossible to reduce the dislocation. Some patients adapt their movements to the limited function of the joint, while others find a congenital dislocation most distressing. The liability to fall, or the loss of complete function of a joint, can often be overcome by some special apparatus designed to meet the peculiar exigencies of the case. If the joint is practically useless and the patient perfectly healthy, the question of forming a new joint by radical operative interference can be considered.

The treatment of pathological dislocation involves the question of exsection of the diseased joint with the formation of a false joint. The results have been in some cases most satisfactory. The operation must be performed according to the general principles involved in exsection of diseased joints.

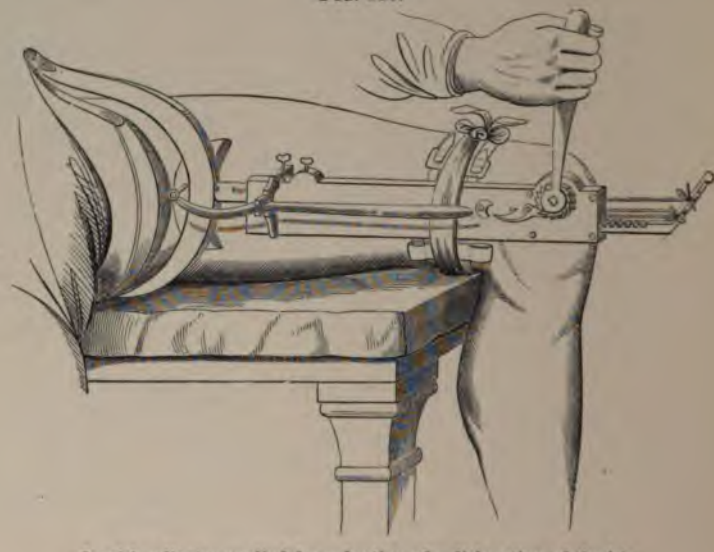
The treatment of the traumatic variety consists in immediately reducing the dislocation. The object can be accomplished by manipulation or by extension and counter-extension. The manipulative method is the simplest, and is generally successful if attempted during the relaxation of the muscles consequent upon shock or anæsthesia. If reaction from shock has taken place and the muscles are in a condition of spasmodic contraction, an anæsthetic is indicated, since the muscles become at once relaxed and the reduction is accomplished without any difficulty.

In employing manipulation the surgeon endeavors to reduce the dislocation by relaxing those muscles which by their contraction prevent the return of the head of the bone into the socket, and also by certain movements to make the head of the dislocated bone travel back by the

same route by which it made its escape from the joint. If manipulation fails to restore the joint to its normal condition, the use of extension and counter-extension is indicated.

In employing *extension* and *counter-extension* the surgeon endeavors

FIG. 129.



Jarvis's adjuster applied for reduction of a dislocation of the hip.

to overcome by force the contraction of the muscles which act as the chief barriers to the reduction of the dislocation. The object is to overcome all sources of resistance of whatever kind by the application of a

FIG. 130.

Reduction of a dislocation on the dorsum ilii by the Spanish windlass (Gilbert).

force sufficient to accomplish the end. Many serious accidents have happened in trying to reduce old dislocations by a too violent exercise of force. Limbs have been entirely torn from the body, large arteries

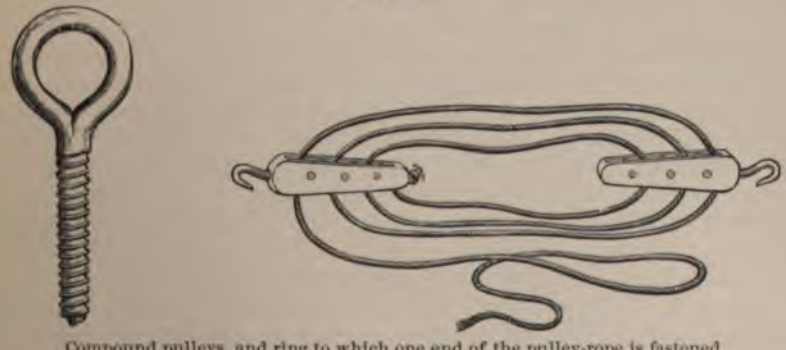
have been ruptured, important veins have been torn, main nerve-trunks have been irreparably lacerated, bones have been fractured, muscles and fascia have been torn from their insertions, and gangrene of the limb has been produced. All these accidents have occurred, and in some cases with fatal results. Since the introduction of anæsthetics these fatalities have been numerically lessened, but it must not be forgotten that the influence of the anæsthetic is in itself a source of very great danger.

Jarvis's adjuster (Fig. 129) is one of the means which are employed to reduce old dislocations. The instrument is so constructed that extension is made by a ratchet, and counter-extension by a perineal band attached to a long shaft fixed to the limb. The Spanish windlass (Fig. 130), as suggested by Gilbert, and the Bloxam "dislocation tourniquet" (Fig. 131) are also employed. Hippocrates designed an instrument for the purpose of reducing old dislocations. There are other instruments with certain mechanical variations, all of which have one common object in view. It seems unnecessary to give any special description of the different varieties of apparatus proposed for this purpose, since their employment has been practically abandoned on account of the introduction of manipulation under anæsthesia, and, in the event of failure to reduce the dislocation by this method, it is preferable to cut down directly upon the joint and divide all structures offering any obstruction to the reduction, scraping out the joint-cavity if necessary, and returning the head of the bone into its proper place. This operation, with every antiseptic precaution, is immeasurably safer than the use of any of the powerful instruments, with the exception perhaps of the compound pulleys (Fig. 132), which can be used with a certain amount of safety in careful hands. Malgaigne has laid down the rule that no force beyond 440 pounds should ever be employed, and a dynamometer should be attached to the pulleys in order to ascertain the precise amount of force exercised.

FIG. 131.

Bloxam's dislocation tourniquet.

FIG. 132.



Compound pulleys, and ring to which one end of the pulley-rope is fastened.

In some cases specially-constructed forceps, or the Indian puzzle (see page 626), or the clove-hitch (Fig. 133) with a wet towel, may be employed

FIG. 133.

Clove-hitch (Erichsen).

with comparative safety under the influence of an anæsthetic. Subcutaneous division of tendons often aids the surgeon in the accomplishment of his object, and this simple operation cannot be too highly recommended.

Too prolonged extension should never be employed, since serious damage can arise from this cause. No surgeon should continue permanent extension over twenty consecutive minutes. All adhesions should be broken up as far as possible before applying the extending and counter-extending force, as this is often of signal benefit in anticipation of, and in conjunction with, the employment of forced extension.

After a dislocation has been successfully reduced the joint should be immovably fixed for at least a week, after which time the dressings should be removed, and a slight amount of passive motion employed to prevent adhesions and to overcome any contraction of the muscles and ligaments. Active motion should not be permitted for at least a fortnight, and in some joints not for a month, since this might provoke inflammatory reaction, tear anew the capsule, and cause a recurrence of the dislocation. In case any stiffness or rigidity of the joint remains, galvanism, massage, shampooing, and inunctions of oil often assist in restoring the usefulness of the joint.

The general treatment of compound dislocations is largely influenced by the particular joint involved and the extent of the joint-injury. Besides the displacement, the soft tissues about the joint are lacerated, the ligaments are torn, the "synovial" capsule is opened, and the tendons, muscles, and vessels are ruptured. In some cases a fracture coexists, and this extensive damage gives rise to inflammation, suppurative arthritis, abscess, cellulitis, and even gangrene. The condition which confronts the surgeon is serious, not only for the future usefulness of the joint, but for the life of the patient. There are three plans of treatment which must be considered—*conservative surgery*, *primary resection of the joint*, and *amputation*. The general rules governing the surgeon in this dilemma have already been mentioned, and consist of consideration of the special joint involved, the age, constitution, and hygenic surroundings of the patient.

Conservative treatment involves the question of the preservation of the

joint, without at the same time exposing the patient's life to too great a risk. In all the joints, except the knee, if the skin is not seriously damaged and the vessels are uninjured, conservatism can be practised. In the case of the knee this plan can be adopted only if the vessels are uninjured, the patient is young and healthy, and the wound in the soft parts small. To meet with success in the conservative plan the soft parts about the joint should be rendered immediately aseptic, the wound if small should be sufficiently enlarged to enable the surgeon to explore thoroughly the joint, which should be irrigated with a warm bichloride solution of 1 : 10,000, and then a large-sized rubber drainage-tube introduced into and through the joint, so that one end at least is in the dependent portion of the joint. The enlarged wound can be sutured so as to close it sufficiently to allow the tube to project flush with the surface of the skin. The parts are now thoroughly again irrigated, and antiseptic dressings applied, over which absorbent cotton should be placed so as to include the entire limb, and a plaster-of-Paris bandage supported with a few strips of tin or zinc to strengthen it. In three to five days a fenestrum should be cut, the joint again irrigated through the tube, which, if the temperature, pulse, and respiration are normal, can either be entirely removed or at least shortened, and finally removed at a subsequent dressing in forty-eight hours. This dressing should be conducted with the same antiseptic precautions and under continuous irrigation, precisely in the same manner as the initial dressing. The plaster should remain on for at least four weeks, and then gentle passive motion should be employed, and at the expiration of two additional weeks a limited amount of active motion should be permitted. If this plan has failed, suppurative arthritis ensues, and a secondary resection or amputation must be performed.

Primary excision of the joint is the second plan of treatment when it is not considered best to attempt conservative measures. In this case the joint is widely opened, the loose pieces of comminuted bone are removed, the torn fascia is cut away, and the wound is rendered aseptic. In the shoulder-, elbow-, wrist-, and ankle-joints a movable joint should be secured, while in the knee an osseous ankylosis is probable. Primary excisions are very unfavorable as compared with secondary resections, and a case of primary excision under these conditions gives rise to great anxiety.

Primary amputation is indicated where it is not best to attempt either a conservative plan or a primary excision, and therefore embraces a class of cases found in elderly persons in whom the joint is seriously damaged and the main vessels are torn.

DISLOCATION OF THE RIBS is seldom observed, since they have very limited motion and great elasticity, and are held together by strong ligaments. The ribs may be separated from the bodies of the vertebræ in fracture of the spine, in which case the head of the rib is found lying upon the front of the spine. The ribs may also be dislocated in consequence of severe falls, or even blows upon the back, with or without fracture of the spine.

The **signs and symptoms** of this dislocation are obscure, and are generally arrived at by exclusion. There is a depression, with no crepitus, but with a peculiar grating sound, caused by the head of the rib

riding on the front of the spine when the rib is pushed from the front; the pain is sometimes very severe.

The **treatment** is substantially the same as it would be in fracture of the bone.

DISLOCATION OF THE CARTILAGES from the sternum occurs especially in young people. The first rib, having no synovial capsule and true joint, is so protected that it is not liable to dislocation. The second to the seventh ribs may become dislocated at their junction with the sternum. The accident may be complicated with fracture of the sternum.

COSTO-STERNAL DISLOCATION may occur as a result of a blow, or in consequence of a sudden violent compression of the chest, or even by muscular action.

The **signs and symptoms** are the presence of a subcutaneous tumor upon the front of the sternum, produced by the dislocated cartilage, and severe pain over the site of the injury.

The **treatment** consists in reducing the dislocation by making the patient assume the position of opisthotonos and pushing the projecting end into its proper place. If the patient is unable voluntarily to assume this position, a sand-bag can be placed between the scapulæ and the shoulders pushed back, when the dislocated end will usually resume its normal position. A firm, hard compress should be placed over the dislocated cartilage and held *in sitû* by broad strips of adhesive plaster, which should encircle the thorax.

DISLOCATION OF THE SIXTH TO THE TENTH CARTILAGES from one another occurs as a result of a fall upon the back or in consequence of a violent contraction of the pectoral or abdominal muscles. The upper margin of the lower cartilage slips beneath the upper cartilage.

The **signs and symptoms** are severe pain and prominence of the cartilage.

The **treatment** consists in instructing the patient to take a deep, full inspiration, and then attempting to disengage the dislocated cartilage. The same kind of a bandage which is employed in fracture of the rib should be applied with a compress over the site of the lesion. This will help to hold the dislocated end in place and serve also to restrain the movements of the thoracic parietes.

DISLOCATION OF THE STERNUM occurs at the junction of the manubrium with the gladiolus, where an arthrodial joint exists. The injury is caused in the same manner as a fracture, presents many of the same signs and symptoms, and requires the same treatment.

DISLOCATIONS OF THE CLAVICLE occur either at the sternal or acromial end. These dislocations are extremely rare, on account of the strength of the short ligaments, and in this respect differ from fractures of the clavicle, which are exceedingly common. Dislocation of the clavicle at the sternal end may be forward, backward, or upward.

The *forward* dislocation is caused by some violence applied to the acromial end of the clavicle, by a fall upon the front of the shoulder, or in bending the shoulder suddenly backward in certain gymnastic movements. The writer has seen a dislocation of the clavicle occur in playing lawn tennis. The dislocated end of the clavicle lies upon the front of the sternum just beneath the articular facet, and upon the sternal origin of the sterno-cleido-mastoid muscle (Fig. 134).

The signs and symptoms consist of a subcutaneous tumor, producing a prominence upon the front of the manubrium; the abrupt ending of the clavicle; the shortening between the shoulder and the mesial line of the sternum as compared with the opposite side; the inclination of the head to the affected side, owing to the fact that the sterno-cleido-mastoid muscle is made tense by the protrusion of the clavicle against it; and severe pain, increased by any movement.

FIG. 134.

Dislocation of the sternal end of the clavicle forward.

The **treatment** consists in drawing back simultaneously both shoulders by placing the knee in the interscapular space, and then having the end pushed into its proper place. A firm compress should be immediately applied over the site of the dislocation and held *in sitû* by adhesive plaster and bandages. If the dislocated end has a tendency to slip out, and thus to cause the deformity to reappear, and if all the circumstances are favorable, the dislocated end can be fastened by a metallic suture.

Dislocation of the clavicle backward occurs in consequence of a kick from a horse or a fall upon the shoulder. The dislocation may be a pathological one, secondary to lateral curvature of the spine. The dislocated end may be thrust backward and slightly upward, just above its natural position, or it may be pushed downward just behind the sternum, beneath the articulating facet, near the origins of the sterno-hyoid and sterno-mastoid muscles.

The **signs and symptoms** consist of pain, loss of function of the affected arm, turning of the head toward the dislocated side, approximation of the shoulder to the mesial line of the sternum, a fossa at the articular facet, dyspnœa from pressure on the trachea, or dysphagia from compression of the œsophagus, or disturbance in both respiration and deglutition if the dislocated end is driven down behind the sternum. If the end of the bone descends low enough, it may by pressure on the subclavian artery cause diminution or cessation of the radial pulse, or by pressure upon the brachio-cephalic vein prevent the return current in the vessel and cause passive hyperæmia.

FIG. 135.

Dislocation of the sternal end of the clavicle upward.

Treatment.—The dislocation can usually be reduced by the means already described, but in case the bone cannot be returned to its proper position, and difficulty of respiration and deglutition is present, the end of the bone should be sawed off to relieve the pressure. This procedure, however, is seldom necessary.

Dislocation of the clavicle upward occurs as a result of indirect violence, and is exceedingly rare.

The **signs and symptoms** are tumor, formed by the projecting end just beneath the insertion of the sterno-cleido-mastoid muscle (Fig. 135);

shortening from the tip of the shoulder to the mesial line of the sternum; occasional dyspnœa from pressure-effects; and sometimes dysphagia.

The **treatment** is substantially the same as has already been described in connection with other dislocations of this bone. In addition, an axillary pad can be employed as a fulcrum, so as to use the arm as a lever, and thus the clavicle can be drawn away from the mesial line, and its dislocated end by manipulation be pushed into the articulating socket, where it can be retained by compresses and a Velpeau dressing, with the elbow brought well forward. It is often very difficult to keep the dislocated end in place, and if the arm is rendered useless by the permanently unreduced dislocation, it can be wired to the sternum by an antiseptic operation.

Dislocations of the acromial end of the clavicle are not so frequent as at the sternal end, on account of the strong conoid and trapezoid ligaments which bind this part of the clavicle down to the scapula. The accident usually occurs as a result of a severe blow upon the back part of the shoulder or of a fall from a height upon the outer part of the shoulder. The bone may be dislocated upward or downward. In the upward variety the end of the bone is found upon the superior surface of the acromion process of the scapula.

Besides the presence of the tumor, the **signs and symptoms** are severe pain, inability to use the arm, depression of the affected shoulder, approximation of the shoulder to the mesial line of the sternum, lengthening of the arm, which hangs close to the side of the thorax, and contraction of the clavicular portion of the trapezius muscle.

The **treatment** consists in reducing the dislocated end by pushing it down into its socket after drawing the shoulder well backward. The axillary pad may be necessary, in which case it acts as a fulcrum and the humerus as a lever. Sometimes the arm can be raised to a right angle with the trunk, and in this position the dislocation will slip into place. The trapezius muscle has a tendency to elevate the dislocated end, and if it can be isolated and divided by a tenotome, the displaced end will be held in place until the tendon has united. When the bone has been reduced great difficulty is found in holding it in place. Compresses have been used over the end, and these bound down firmly by long strips of rubber or adhesive plaster. The skin soon becomes excoriated by the plaster, and the patient is unable to tolerate the dressing. In these cases the metallic suture under proper antiseptic precautions is indicated, and the bone can thus be permanently fixed in its proper position.

Dislocation of the acromial end downward is an exceedingly rare accident. The injury is the result of a blow from above directly upon the clavicle, or a fall in which the body is thrown forward and the force of the fall impinges upon the upper surface of the clavicle. In this dislocation the acromio-clavicular ligaments are ruptured, and the end of the bone rests upon the capsule of the shoulder-joint, or it may descend and be found beneath the coracoid process of the scapula.

The **signs and symptoms** are projection inward of the superior angle of the scapula and protrusion outward of the inferior angle of the same bone, great pain and tenderness, marked depression over the inner side of the acromion, inability to move the arm, and projection of the coronoid process.

The **treatment** consists in reducing the dislocation by drawing the shoulders outward and backward and pushing the inferior angle of the scapula inward. The scapula should be held *in sitû* by compresses in a manner similar to that described in treating fractures of this bone.

Dislocation of the clavicle simultaneously at the acromion and sternal ends has been reported by a few surgeons. The accident occurred in falls upon the back of the shoulder.

The **signs and symptoms** are those indicated in the respective dislocations, and the **treatment** consists in reduction by the plan already described.

DISLOCATION OF THE SCAPULA occurs as a result of the bone slipping from under the tendon of the latissimus dorsi muscle, which traverses and covers the inferior angle of the scapula. This bone may also become dislocated as a result of paralysis of the serratus magnus muscle or the long thoracic nerve.

The **signs and symptoms** are a wing-like projection of the dorsal border of the inferior angle of the scapula, and loss of motion in certain movements of the arm and shoulder.

The **treatment** consists in replacing the bone under the latissimus dorsi tendon and holding it in its proper position by compresses, which in turn are held in place by some apparatus similar to that employed in fracture of the rib. If the displacement is due to paralysis of the muscle, hypodermic injections of strychnia into its substance, combined with the use of electricity, iron, and massage, will often relieve the trouble.

DISLOCATION OF THE SHOULDER-JOINT occurs more frequently than dislocation of any other joint in the body, forming a little over 50 per cent. of all dislocations. This fact is due to certain anatomical features of the joint, such as great freedom of motion, shallowness of glenoid cavity, laxity of capsular ligament, absence of muscles adapted to give support and strength, and, finally, to the immense leverage owing to the length of the upper extremity.

The shoulder may be dislocated by *indirect violence*, as a fall upon the elbow or hand, or by *direct violence*, as a severe blow upon the anterior or posterior part of the shoulder while the arm is separated from the body, or, finally, by *muscular action*.

The **varieties** of dislocation of the shoulder are subcoracoid, subglenoid, subspinous, and subclavicular.

The *subcoracoid variety* is the most frequent. The head of the bone lies under the coracoid process of the scapula (Fig. 136), and escapes from the joint through a tear in the inner and lower part of the capsule, where the opening of the biceps bursa begins. The anatomical neck lies upon the anterior lip of the glenoid cavity, and the posterior part of the capsule is stretched tightly across the glenoid fossa. The tendon of the biceps is usually pulled out of its groove, and the muscles attached to the tuberosity are torn from their insertion into the bone. In this variety the axillary vessels are usually not pressed upon by the head of the bone.

The *subglenoid variety* appears next in point of frequency, and the head of the bone escapes either below the insertion of the subscapularis muscle (Fig. 137) or forces its way through the substance of the muscle itself. The capsule is torn below, and the head of the bone causes

compression of the axillary vessels and nerves, which results in œdema, cyanosis, and great pain.

The *subclavicular variety* is rare. The head of the bone is carried to the inner side of the coracoid process beneath and across the pectoral

FIG. 136.

Subcoracoid dislocation of the shoulder.

FIG. 137.

Subglenoid dislocation of the humerus.

muscle, and is prominent under the skin. In this variety the external rotators attached to the greater tuberosity are completely torn from their insertion, or else the bony process is fractured. This dislocation is the result of great violence (Fig. 138).

FIG. 138.

Dislocation of the shoulder downward under the clavicle.

FIG. 139.

Subspinous dislocation of the shoulder, unreduced; new socket formed.

The *subspinous variety* is found where the posterior and lower part of the capsule has been torn (Fig. 139), and the head of the bone is forced to rest upon the dorsal surface of the scapula below the spine and beneath the infraspinatus muscle. In this variety the subscap-

ularis muscle is stretched across the glenoid cavity in the same manner as the external rotators are in the forward varieties of dislocation.

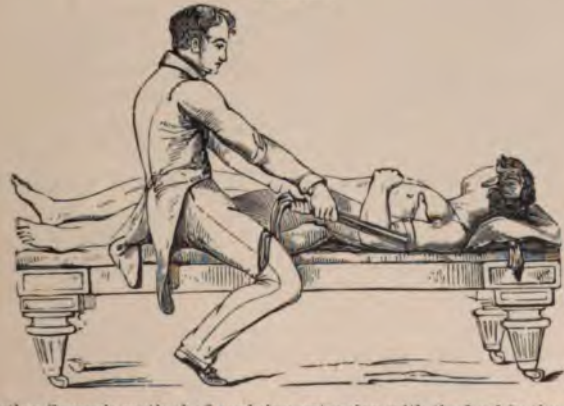
In addition to these four varieties, occasionally there are slight departures from the ordinary types—for example, subacromial or supra-coracoid—but a careful examination of the injured joint will demonstrate the fact that these variations are different in degree and not in kind.

The **signs and symptoms** of dislocation of the shoulder are very similar, irrespective of the special variety. They are—flattening of the shoulder; prominence of the acromion; depression beneath the acromion; absence of the head of the bone from the glenoid cavity; preternatural immobility; pain in the joint and along the cords of the brachial plexus; rigidity of the surrounding muscles; inclination of the patient's head toward the affected joint; flexion of the elbow to relax the biceps; obliteration of the infra-clavicular fossa; prominence of the head of the bone under the skin in certain varieties; axis of limb abducted; œdema from mechanical pressure; the affected forearm is supported by the opposite hand; the anterior axillary fold is less prominent; and the head of the bone is felt in the axilla or beneath the skin below the acromion or the clavicle.

In addition to these signs, Hamilton has demonstrated that a ruler placed upon the acromion will touch the external condyle of the humerus in a dislocated joint; Callaway has shown that the vertical measurement over the acromion and around the axilla is some two inches greater upon the affected side; and Dugas has proved that in dislocation of the shoulder the hand cannot touch the opposite shoulder if the elbow of the affected side is brought in contact with the thorax.

The **signs** of dislocation of the shoulder must be distinguished from those of fractures of the upper end of the humerus and of the neck of the scapula, and from those of paralysis of the deltoid muscle.

FIG. 140.



Sir Astley Cooper's method of applying extension with the heel in the axilla.

Paralysis of the deltoid is diagnosticated by the presence of unusual mobility in the joint, by the relaxation of the muscles, by inability to raise the arm at right angles to the trunk, by the negative results of Dugas's and

Callaway's tests, and, finally, by the presence of the head of the humerus in the glenoid cavity. This condition can also be ascribed to some traumatism affecting the deltoid muscle.

THE FRACTURES OF THE UPPER END OF THE HUMERUS, including those of the anatomical and surgical neck and the tuberosity, are distinguished by the signs already given under Fractures. The fracture of the neck of the scapula, besides the ordinary signs of fracture, has one peculiarity—viz. the deformity can be at once removed by simply lifting the entire arm upward, when the normal relations of the joint are immediately restored, but only so long as the arm is supported by the surgeon, since withdrawal of the support is followed by a return of the deformity.

The **treatment** of dislocation of the humerus may be accomplished by Kocher's method, by flexion of the forearm upon the arm to a right angle and then bringing it close to the side. The surgeon then grasps the forearm thus flexed and turns it away from the body as far as possible, to cause external rotation of the arm. During this movement the head of the bone rolls outward in front of and below the acromion, the elbow is then carried well forward and upward, and then the arm is rotated inward and the elbow lowered. Manipulation by an assistant with his hand in the axilla is often of great service.

FIG. 141.

Sir Astley Cooper's mode of operating with the knee in the axilla.

Sir Astley Cooper's method consists in the surgeon making extension with his foot in the axilla while the patient lies upon the edge of a table or upon the floor (Fig. 140).

The same method can be employed by the surgeon standing behind and placing his knee in the axilla of the patient, who is seated upon a low stool. The surgeon now presses down upon the acromion process (Fig. 141) with one hand and makes traction downward upon the arm with the other hand, while at the same time he raises his heel so as to push the head of the bone outward. This method combines extension, leverage, and abduction with manipulation.

Skey used an iron knob (Fig. 142) in place of the heel in the axilla, in conjunction with the use of compound pulleys (Fig. 143).

FIG. 142.

Iron knob employed by Skey, instead of the heel.

Wood reduced these dislocations by having an assistant stand upon a firm table and make counter-extension with a towel passed under the

axilla of the patient, who stands by the side of the table while the surgeon makes extension from the arm below.

H. H. Smith employed the following method: "Elevate the elbow and arm as high as possible and flex the forearm at right angles with the arm, thus relaxing the supraspinatus muscle. Then, using the forearm

FIG. 143.

Skey's method of making extension and counter-extension with pulley.

as a lever, rotate the head of the humerus upward and forward, so as to relax the infraspinatus muscle, carrying the rotation as far as possible or until resisted by the action of the subscapularis muscle, keeping the forearm for a few seconds in its position with the palm of the hand looking upward; then bring the elbow promptly but steadily down to the side, carrying the elbow toward the body and keeping the forearm so that the palm of the hand yet looks to the surgeon. Then quickly but gently rotate the head of the humerus upward and outward by carrying the palm of the hand downward and across the patient's body, and the bone will usually be replaced."

DISLOCATIONS OF THE ELBOW-JOINT occur very frequently in young persons: 50 per cent. of the cases are said to be found in persons under fifteen years of age. This dislocation is therefore an exception to the rule that dislocations are usually observed during adult life. It is generally the result of direct violence by a fall upon the palm of the hand or upon the inner side of the forearm or upon the olecranon. It has also been observed as a result of a twist to the ulna in which the coronoid process is drawn downward, inward, and backward. There are several varieties, some affecting both bones of the forearm, others the radius alone, and still others the ulna. The varieties affecting both bones are *backward*, *forward*, *outward*, and *inward*; those involving the radius alone are *backward*, *forward*, and *outward*; and that involving the ulna, *backward*.

Before describing the different dislocations of the elbow-joint it is very important to a complete understanding of these various injuries to study the anatomical relations of the normal joint. The external condyle of the humerus, the olecranon, and the internal condyle of the humerus should be in a transverse line across the posterior part of the joint when the forearm is extended upon the arm. Any deviation from this normal relation indicates a dislocation or a fracture.

The **signs and symptoms** of dislocation of both bones of the elbow-

joint backward, the most frequent variety, are—projection of the olecranon backward; stretching of the triceps over the lower exposed surface of the humerus; exposure of the articulating surface of the humerus; shortening of the forearm; fixation, partial flexion, and slight pronation of the forearm; crepitus, provided the coronoid process is fractured, and, if it is not fractured, its presence in the olecranon fossa (Fig. 144).

FIG. 144.

Dislocation of radius and ulna backward.

The **signs and symptoms** of dislocation of both bones forward, in which the olecranon is usually fractured, are—lengthening of the forearm; depression in front of arm corresponding to the sigmoid notch; great prominence of the condyles of the humerus; depression behind, where the olecranon belongs, with absence of this process from its normal place, and its presence in the trochlear fossa on the front of the condyles of the humerus.

The **signs and symptoms** of dislocation of both bones outward or to the radial side (Fig. 145) are—flexion and immobility of the forearm; pronation of the forearm, with the head of the radius upon the outside of the joint and rotating just beneath the skin; and great prominence of the internal condyle of the humerus. This dislocation is incomplete, since the ulna catches against the external condyle.

FIG. 145.

Dislocation of the head of the radius outward.

The **signs and symptoms** of dislocation of both bones inward or to the ulnar side consist of prominence of the external condyle, flexion of the forearm and pronation of the hand, and the presence of the olecranon process upon the inner side of the joint. This dislocation is not as common as the preceding one, on account of the obliquity of the articulating surface, which is higher internally.

The **signs and symptoms** of dislocation of the radius backward are absence of the head of the radius from its normal place and its presence behind the external condyle beneath the skin, and fixation of the forearm. In this dislocation fracture of the external condyle often coexists.

The **signs and symptoms** of dislocation of the radius forward (Fig. 146) are—flexion and semi-pronation of the forearm; head of the radius upon the front of the external condyle; a depression upon the radial side of the forearm; and inability com-

pletely to flex the forearm, owing to the fact that the head of the bone impinges against the external condyle.

The **sign** of dislocation of the radius outward consists of the presence

FIG. 146.

Dislocation of radius forward.

of the head of the radius upon the outer side of the external condyle, just beneath the skin, which is stretched tightly over it.

The **signs and symptoms** of dislocation of the ulna backward (Fig. 147) are—projection of the ulna behind, rotation of head of radius in its normal socket, crepitus if the coronoid process is fractured, pronation of the hand, and great shortening of the forearm upon its ulnar side.

FIG. 147.

Dislocation of the upper end of the ulna backward.

The **treatment** of dislocations of the elbow-joint consists of fixation of the humerus, flexion or extension of the forearm, and digital pressure of the dislocated end, so as to push it into the joint-socket. In case of dislocation of both bones or of the ulna alone, the extension should be made by grasping firmly the forearm; if of the radius alone, the extending force should be applied from the hand. It is seldom necessary to give an anæsthetic, but if it is employed the reduction can be easily effected. After reduction cold evaporating lotions of lead-opium wash or Goulard's extract, or some stimulating liniment, should be applied to the joint for a few days until all inflammatory action has subsided. In a fortnight gentle passive motion should be employed.

DISLOCATIONS OF THE WRIST-JOINT are extremely rare. Dupuytren has stated that this dislocation never occurs. This would apply to intra-carpal dislocations, but not to *wrist-joint* dislocations, as shown below in Figs. 148 and 149. The author has observed four well-marked cases of this injury—one in private practice and three in hospital service—one of which was compound.

The **causes** of dislocation of the wrist-joint are falls upon the palm with the hand bent forward. The impacted fracture of the lower end of the radius simulates this injury to some extent.

The **varieties** are *backward* and *forward*.

The **signs and symptoms** in the *backward* variety consist of a dorsal prominence, produced by the carpus overlapping the lower end of the radius (Fig. 148); the hand lies on a plane superior to the forearm, and

Fig. 148.

Dislocation of the carpal bones backward (Fergusson).

the continuity of the parts is thus destroyed; the forearm is shortened from the elbow to the tips of the fingers; there is absence of crepitus, and, if the deformity is reduced, there is no tendency to return.

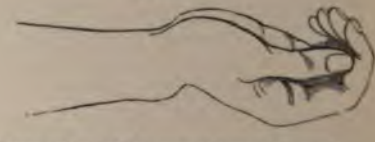
The **signs and symptoms** in the *forward* variety of dislocation of the wrist-joint consist of a palmar prominence produced by the carpus sliding up upon the anterior surface of the radius; the hand is on a plane inferior to the forearm (Figs. 149 and 150). The remaining signs are similar to those in the backward dislocation.

The **differential diagnosis** of either of these dislocations from Colles's fracture is made by the absence of the characteristic signs of fracture and the disturbed relation of the styloid processes to the bones; in sprains all the characteristic signs of dislocation and fracture are absent; in ganglia, the presence of fluid, ascertained by the use of a hypodermic needle, and the peculiar deformity caused by the fluid dipping under the annular ligament, are characteristic.

Fig. 149.

Dislocation of the carpal bones forward.

Fig. 150.



Dislocation of the carpal bones forward.

The **treatment** consists in adopting the general principles laid down in reducing any dislocation by extension and counter-extension. After the reduction is effected the hand should be placed upon an antero-posterior splint and kept at rest for several weeks.

In one case of compound dislocation which the author had under treatment the ulnar artery was ruptured and gangrene of the hand ensued, which condition led to amputation of the forearm.

DISLOCATION OF THE PROXIMAL PHALANX OF THE THUMB occurs as a result of a blow or a fall upon the distal end and palmar surface of the thumb, so as to cause forced extension.

There are two **varieties**, the *backward* and the *forward*, and the

FIG. 151.

Unreduced dislocation of the thumb (Ashhurst).

signs and symptoms are too evident to require any special description (Fig. 151). This is often the most difficult dislocation in the body to reduce, and also, at times, the most easily reduced of all dislocations (Fig. 152).

FIG. 152.

Dislocation of the metacarpo-phalangeal joint of the thumb.

There have been many reasons assigned to explain the occasional difficulty of reducing this dislocation. Erichsen thinks that the head of the metacarpal bone becomes locked between the two heads of the flexor brevis pollicis; Cooper believed the difficulty to be due to the presence of six powerful muscles; Hey thought that the obstacle to reduction lies in the fact that the head of the bone is constricted between the lateral ligaments of the joint; Dupuytren held the view that the lateral ligaments, which normally are parallel, are in this injury at right angles to the axis of the metacarpal bone. The infolding of the anterior ligament and the intervention of a sesamoid bone between the joint-surfaces have also been assigned as obstacles to reduction.

The **treatment** consists in the application of extension and flexion in many different ways. Cooper suggested bending the thumb toward the palm in order to relax the flexors, and then applying a clove-hitch to the

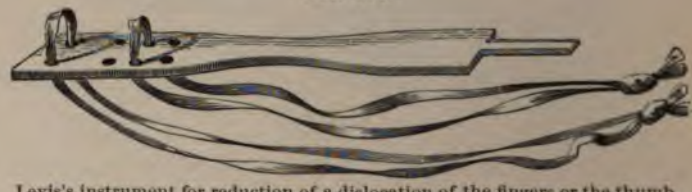
distal phalanx; Bell suggested division of the lateral ligaments; Roser recommended extreme dorsal flexion, with a view to increase the amount of extension. Various instruments have been devised, such as the Indian puzzle (Fig. 153) and Levis's instrument (Figs. 154 and 155).

FIG. 153.

"Indian puzzle," employed for the reduction of dislocations in small joints.

In certain cases, after every method fails, a resection of the head of the bone is indicated The author has performed this operation in two

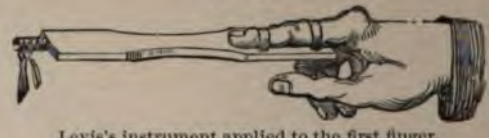
FIG. 154.



Levis's instrument for reduction of a dislocation of the fingers or the thumb.

cases where, after repeated trials under anæsthesia, reduction could not be effected. The joint-wound healed by primary intention, and the

FIG. 155.



Levis's instrument applied to the first finger.

function of the joint was so completely restored as to afford no inconvenience to the patient.

DISLOCATION OF THE PHALANGES often occurs, and is the result of mechanical violence.

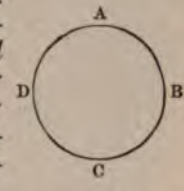
The **signs and symptoms** are too apparent to require any special description.

The **treatment** consists in reducing the dislocation by extension and counter-extension, and placing the finger on a splint and applying a few turns of plaster-of-Paris bandage to keep the parts quiet until the ligaments are healed. It may be necessary after the removal of the splint to employ gentle passive motion until the function of the joint is fully restored.

DISLOCATIONS OF THE HIP form about 9 per cent. of all dislocations. The wide range of motion which this joint enjoys explains, in a measure, the frequency of this special injury as compared with other dislocations in the lower extremity. Albert has shown that the hip-joint can be flexed and extended to an angle of 140° if only the bones and ligaments

are attached, and abduction and adduction at an angle of 90° to 100° can be produced under the same conditions. If the muscles are in place, flexion is diminished to about 30°, and adduction to 20°. He has thus demonstrated that extension and abduction are limited by the ligaments, while flexion and adduction are limited by the muscles or by mechanical obstacles, such as the limb meeting the abdomen. In regard to age, cases have been reported from the extremes of life, one case at six months and another in the ninety-second year.

There are four different **varieties** of dislocation of the hip. They can be classified according to the frequency of occurrence and also by the employment of a figure which illustrates the anatomical arrangement. If a circle is drawn, A represents the *upward* dislocation on the dorsum ilii; B, the *backward* variety into the ischiatic notch; C, the *downward* variety into the obturator foramen; and D, the *forward* variety upon the os pubis. In studying the varieties of dislocation it is well to adopt a definite plan, which can be applied to all the different varieties.



The first variety of dislocation is *upward*, and forms about one-half of all the cases. The head of the bone lies upon the dorsum ilii (Fig. 156)

FIG. 156.

Dislocation of the femur upon the dorsum ilii.

and upon or under the gluteus minimus muscle. The injury is usually produced by a fall upon the outer side of the knee or foot when the limb is abducted and thrown forward.

The **signs and symptoms** of this dislocation can be best enumerated if the surgeon begins his examination by first inspecting the toe, then the foot, knee, thigh, trochanter major, limb, and gluteo-femoral fold, in the

order mentioned, from below upward. By this plan he can readily detect the variety of dislocation. In this first variety the toe is turned toward the opposite instep; the foot is inverted; the knee is slightly flexed, and touches or is nearly in contact with the upper margin of the opposite patella; the thigh is rotated inward, slightly flexed, and adducted; the trochanter major is more prominent, and is distinctly felt; the entire limb is shortened about two inches; and the gluteo-femoral fold is higher than upon the opposite side.

FIG. 157.

Dislocation of the femur backward into the ischiatic notch.

There are only two injuries which could possibly be mistaken for d li
location upon the dorsum ilii. The first injury is *fracture of the neck* o
the thigh-bone, in which crepitus, mobility, eversion of the foot, l es
amount of shortening, less prominence of the trochanter major, and it
occurrence in an aged patient, are the differential points. The sec nt
injury is *contusion of the hip-joint*, in which the absence of crepitus, the
presence of the head of the bone in the acetabulum, the absence of sh rt-

ening, and the tests made by Nélaton's line and Bryant's triangle (see page 567) form a group of signs which serve to characterize the nature of the injury.

The second variety of dislocation is *backward* into the ischiatic notch (Fig. 157). The injury results from a fall upon the knee or foot while the limb is in front of the body.

Adopting the plan of description given for the preceding variety, the toe is turned toward the opposite toe; the foot is inverted; the knee is slightly flexed; the thigh is rotated inward, flexed, and adducted; the trochanter major is prominent and is distinctly felt, and is nearer the anterior superior spinous process of the ilium; the limb is shortened about one inch; the gluteo-femoral fold is higher than normal and the head of the bone can be felt in the notch if the finger is introduced into the rectum or the vagina. The two injuries that might be mistaken for this dislocation are those described under the preceding variety.

FIG. 158.

Dislocation of the femur downward into the obturator foramen.

The third variety of dislocation of the hip is *downward* into the obturator foramen (Fig. 158). The head of the bone lies upon the obturator externus muscle. The injury is caused by a fall when the leg is abducted.

The toe points downward and forward; the foot points forward and is everted; the knee is slightly flexed; the thigh is slightly flexed and abducted; the trochanter major is flattened and is nearer the mesial line; the entire limb is lengthened about two inches; and the gluteo-femoral fold is obliterated.

The fourth variety of dislocation of the hip is *forward* upon the horizontal portion of the os pubis (Fig. 159). The head of the bone lies

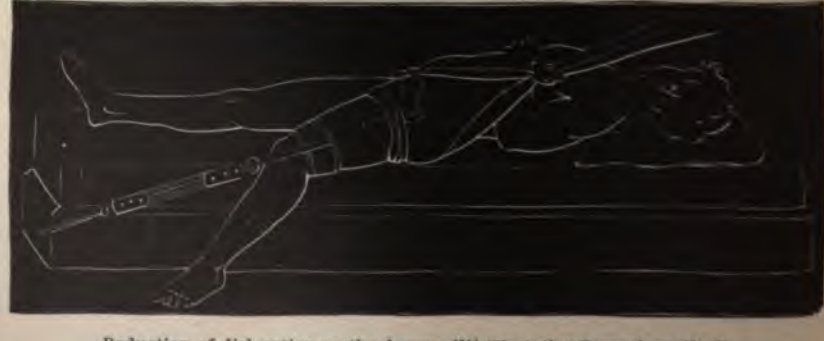
FIG. 159.

Dislocation of the femur forward upon the os pubis.

upon the outer side of the femoral artery and above Poupart's ligament. The injury is produced by a fall when the limb is thrown backward and behind the centre of gravity.

Adopting again the same plan of description, the toe points outward; the foot is everted; the knee is slightly flexed; the thigh is rotated out-

FIG. 160.



Reduction of dislocation on the dorsum ilii (Sir Astley Cooper's method).

ward, slightly flexed, and abducted; the trochanter major is rotated backward and has lost its prominence; the entire limb is shortened about half an inch; and the gluteo-femoral fold is obliterated.

FIG. 161.

Reduction of dislocation into the sciatic notch (Sir A. Cooper's method).

If, now, the *first and second varieties* are considered together, it is evident that the **signs and symptoms** differ only in degree and not in kind, since in both varieties the toe and foot are inverted, the knee flexed and adducted, the thigh rotated inward, with shortening of limb and prominence of the trochanter major, and elevation of the gluteo-femoral folds.

FIG. 162.

Dislocation into the obturator foramen.

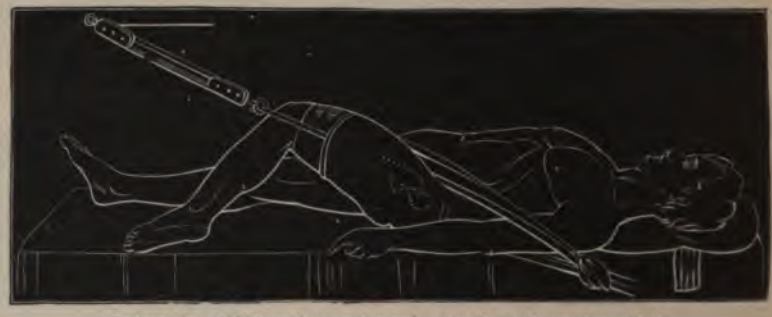
If the *third and fourth varieties* are considered together, it is evident that many of the **signs and symptoms** differ again only in degree and not in kind, since in both varieties the toe and foot point downward and forward and are everted, the knee is nearly straight, and the trochanter major flattened. In the *downward* dislocation there are two inches of lengthening, while in the *backward* dislocation there is half an inch of shortening. The inversion of the toe and foot in the first and second varieties is due to the outer band of the Y-ligament of Bigelow, since division of this causes the sign of inversion to disappear, as pointed out by Bigelow.

In considering the **treatment** of dislocation of the hip the obstacles which prevent reduction must not be overlooked. They consist of the Y-ligament; the capsule which girds the neck of the bone, the small rent in which prevents the free return of the bone into the joint; the sciatic nerve, which may become entangled by forming a loop around the neck of the bone; the obturator externus tendon, which becomes tense over the back of the neck of the bone; and, finally, the muscles, which often embrace the head in a slit-like aperture. The treatment by manipulation consists in overcoming by certain movements these various obstacles to reduction. The leg is flexed upon the thigh to serve as a

lever for the surgeon; the thigh is then flexed upon the pelvis to relax the Y-ligament. The entire limb is then abducted and rotated outward in the first and second varieties, in order to throw the head of the thigh-bone over the acetabulum, while in the third and fourth varieties the entire limb is adducted and rotated inward. After either of these movements has been executed, according to the variety of dislocation, the limb should be suddenly raised in order to throw the head of the bone over the margin of the acetabulum, after which the limb should be extended in its normal position. Briefly, the two joints are flexed, the limb abducted and pulled outward and lifted, in the first or second variety; or the two joints are flexed, adducted, and pushed inward and lifted in the third or fourth variety. Sir Astley Cooper's methods of reduction by extension are shown in Figs. 160, 161, 162, and 163.

The results of treatment of unreduced dislocation of the hip have not been satisfactory. In six cases reported, only two were reduced by an

FIG. 163.



Reduction of dislocation on the pubes by Sir A. Cooper's method.

operation, and in one of the two cases the patient died as a result of the operation, and the other patient suffered from caries of the bone.

Compound dislocations of the hip are extremely rare, only about a dozen cases ever having been reported. The treatment of such an injury must be conducted on the lines governing the management of compound dislocations in general.

DISLOCATION OF THE KNEE is a serious injury, on account of the damage sustained not only by the blood-vessels, muscles, ligaments, and cartilages, but also by the joint itself, which may undergo suppuration as the result. Fortunately, it is rare, as it occurs in less than 2 per cent. of dislocations, owing to the number and arrangement of the powerful ligaments. The injury occurs as a result of some direct, sudden mechanical violence.

The **varieties** are—*outward* (Fig. 164), *inward* (Fig. 165), *forward* (Fig. 166), *backward* (Fig. 167), and by *rotation*. The second and third varieties are often incomplete. The dislocation occurs *forward* in nearly half the cases, and about 20 per cent. of the forward dislocations are compound.

The **signs and symptoms** are too apparent to require any special description. The irregular appearance of the knee-joint, the unusual prominence of the condyles, the immovably fixed position of the joint,

the increase in the antero-posterior or lateral diameters of the joint, the loss of parallelism in the two limbs in the first and second varieties, or great shortening in the forward and backward varieties, distinguish the

FIG. 164.

Subluxation of the head of the tibia outward.

FIG. 165.

Subluxation of the head of the tibia inward.

nature of the injury. In dislocation by *rotation* the leg is twisted upon its own vertical axis either inward or outward, the latter variety being the more frequent. The appearance is so characteristic that a description of the signs and symptoms is unnecessary.

FIG. 166.

Subluxation of the head of the tibia forward.

FIG. 167.

Complete dislocation of head of the tibia backward.

The **treatment** of dislocation of the knee-joint consists of extension of the leg, with counter-extension from the thigh and pressure of the head of the tibia inward, outward, backward, or forward, according to

the special variety. Care should be taken to avoid hyper-extension of the leg, as the popliteal vessels might be injured. In the dislocation by rotation the reduction is easily effected by twisting the leg in the long axis of the limb in the opposite direction, while extension at the same time is maintained. After reduction of the dislocation the entire limb should be placed in a plaster-of-Paris bandage, and retained in an immovable position for several weeks. Passive motion should be employed after the removal of the splint, and no active movement allowed for another week after the discontinuance of the splint.

Compound dislocation of the knee-joint is a most serious injury, owing to the large size and complicated structure of the joint. If the wound is small and nothing foreign has entered the joint, the aperture can be hermetically sealed with styptic collodion painted over a thin film of absorbent cotton. The wound, including the joint, should be dressed aseptically and the limb placed in a plaster-of-Paris splint. If the wound is barely large enough to admit the finger, the joint should be thoroughly irrigated with warm bichloride-of-mercury solution of the strength of 1 : 10,000, prepared with distilled water. A counter- and dependent opening should be made in order to drain freely the cavity of the joint, and after dressing the knee aseptically the conventional retentive apparatus of plaster of Paris should be applied. If the wound is larger than is sufficient to admit the finger and the soft parts are lacerated, a primary resection should be performed, provided the patient is young, with healthy viscera and organs, and no large vessels or nerves are injured. Under these same conditions primary amputation is indicated when the patient is old, feeble, or affected with visceral disease, or when the main vessels and nerves are injured. Conservative surgery can accomplish much in these days in cases where a few years ago amputation was the only hope for the patient's life. In severe cases thrombus of the popliteal vessels has been observed, and gangrene resulted, requiring immediate amputation.

DISLOCATION OF THE SEMILUNAR CARTILAGES involves a subluxation of the cartilage from its normal position, which may occur in consequence of a sudden twist or wrench in elderly people, or the dislocation may occur as a result of chronic disease of the joint.

In this injury there is sudden loss of the joint-function, attended by excruciating pain, which is often so intense as to cause the patient to faint and to fall to the ground. There are no immediate characteristic signs, as far as the joint is concerned, but the joint soon becomes swollen from effusion and the inflammatory reaction is very great. This dislocation must not be mistaken for a loose cartilage in the joint, which is a chronic condition often recurring with some of the signs of dislocation, only of not so severe a character.

The treatment consists in returning the cartilage to its normal position while the patient is under the influence of an anæsthetic. The patient should be placed upon his back, the surgeon's left arm should be passed under the popliteal space, and the leg seized and flexed by an assistant. This manipulation under anæsthesia separates the joint-surfaces, and the cartilage can be now pushed back into its normal place by the surgeon's right hand. After reduction the ice-cap should be placed

over the joint for twenty-four hours, and then a plaster-of-Paris splint applied over a thick layer of absorbent cotton to produce uniform and equable pressure. If the dislocation has a tendency to recur, the surgeon can cut down upon the loosened and displaced cartilage and suture it to the bone, or even excise it. This operation must be undertaken with every antiseptic precaution. In cases where no operation seems advisable some apparatus should be made to limit the amount of movement in the joint (Fig. 168).

FIG. 168.

Apparatus employed to limit motion in dislocation of the semilunar cartilages.

DISLOCATION OF THE PATELLA occasionally occurs, and forms only about 1 per cent. of all dislocations. The injury may be the result of mechanical violence from a blow or a fall upon the side of the bone, especially when the knee is slightly flexed, or the dislocation may occur from muscular action, or the condition may be congenital.

The **varieties** are *outward*, *inward*, *vertical*, and *upward*. Any of these varieties may be complete or incomplete. The *outward* variety (Fig. 169) is the most common, though the natural plane of the trochlear surface would seem to favor the inward variety.

FIG. 169.

Andrews's case of dislocation of the patella outward.

The **signs and symptoms** of outward dislocation of the patella are flatness of the knee, tense condition of the quadriceps extensor muscle, inability to flex the knee-joint, and the patella resting upon the external condyle.

In the *inward* variety the **signs and symptoms** are similar to the above, except that the signs are found upon the opposite side of the condyle. This variety is always the result of mechanical violence.

The *vertical* or *rotary* variety has been observed upon a few occasions, and is caused by a sharp blow upon the side of the patella when the knee is in the semi-flexed position.

The *upward* variety occurs only with rupture of the ligamentum patellæ. The accident is accompanied by considerable synovitis. The upward dislocation occurs when an attempt is made to prevent one's self from falling backward, or it may follow as a result of falling upon a broken piece of glass or by a sabre cut.

The **treatment** of dislocation of the patella in the outward, inward, and vertical varieties consists in elevating the entire limb, so as to relax the quadriceps extensor muscle, which should be pushed toward the patella while the limb is thus hyper-extended. The bone itself is now pushed by means of digital pressure into its proper position. Hooks have been inserted under the skin to make outward traction, but their use is attended with more or less danger. In the upward variety the ligamentum patellæ must be sutured to its original point of attachment to the tibia at the place from which the tendon has been torn. This operation must be performed with great care and with every antiseptic

precaution, since the close proximity to the knee-joint makes the operation one of more or less gravity. The knee should be placed, after reduction, in a plaster-of-Paris splint. After several weeks the dressing can be removed and an elastic knee-cap applied over the joint, in order to maintain the patella in its proper position, and also to afford greater security to the patient. In the congenital variety a knee-cap should be worn, which has a tendency to prevent the bone from slipping too far out of its place.

DISLOCATION OF THE FIBULA occurs as a result of mechanical violence, muscular action, or disease or arrest of growth of the bone, or some affection of an adjacent joint, or even by lengthening of the tibia or fibula by hypernutrition.

There are two **varieties**—one in the upper part, at the *superior tibio-fibular* articulation, and the other in the lower part, at the *inferior tibio-fibular* articulation. In the first variety the dislocation may be either *forward*, *backward*, or *upward*. This variety is caused by a blow upon the head of the fibula, or by a sudden contraction of the biceps muscle, or by shortening of the tibia in consequence of fracture of the bone. Dislocation in the lower end of the fibula may be also either *forward* or *backward*. In this variety a fracture is often associated with the dislocation.

The **signs and symptoms** are too apparent to require any special description.

The **treatment** consists in pushing the dislocated end back into its place after first relaxing, by flexion, the muscles the contraction of which would interfere with the reduction. If this fails, the knee can be extended with the foot strongly flexed. When the bone is in its proper place a compress should be applied to the dislocated end, and the entire limb placed in a plaster-of-Paris bandage for several weeks.

DISLOCATION OF THE ANKLE-JOINT forms about 3 per cent. of all dislocations. The injury is usually caused by a fall upon the foot, or by a force expended upon the part of the ankle opposite to the dislocation. A fracture is very often associated with this dislocation.

The **varieties** are *outward*, *inward*, *forward*, *backward*, and *upward*. The fibula is usually fractured in the outward, forward, and backward varieties, and the tibia in the inward variety.

In the *outward* dislocation (Fig. 170) the foot is twisted and its plantar surface is turned toward the fibula, the internal lateral ligament is usually torn, and the inner malleolus projects just beneath the skin. This variety is often mistaken for Pott's fracture.

In the *inward* dislocation the internal malleolus is usually fractured; the other side of the foot rests upon the ground, and the inner side of the foot is turned upward.

In the *forward* variety the foot is very much lengthened and the tibia rests upon the upper and posterior part of the os calcis. This form of dislocation is exceedingly rare.

In the *backward* variety the foot is very much shortened, the internal lateral ligament is torn, the external lateral ligament and the fibula are broken, the heel is very prominent, the toes point down, and the end of the tibia is thrown upon the scaphoid and the internal cuneiform bone.

In the *upward* variety the tarsal bones are forced up between the

tibia and fibula, and the ankle-joint is very much increased in its lateral diameter, while the vertical measurement of the foot is much less than normal.

The **treatment** consists in flexing the leg upon the thigh to relax the tendo Achillis, and in making forcible but gradual traction upon

FIG. 170.

Dislocation of the ankle-joint outward.

the foot in the opposite direction to that from which the foot was thrust at the time of the accident. Division of the tendo Achillis may be performed with a view to facilitate the reduction. The foot should be placed at once in a plaster-of-Paris splint, or in lateral wooden splints with holes in the side to correspond to the salient points formed by the two malleoli. In simple dislocation of the ankle the reduction is easily accomplished, and if the joint is given sufficient physiological rest the injury will repair without any difficulty.

Compound dislocation of the ankle-joint was formerly considered a most serious injury. Even in these days, at a time when the technique of aseptic surgery is nearly perfect, the management of these cases is often attended with unsatisfactory results. The mortality in past years was very great, and blood-poisoning was the usual cause of death. At the present day this cause of death has been practically removed, but

the question as to the adoption of the best means of restoring the perfect function of the ankle-joint is a most important one.

There are certain Procrustean rules the strict observance of which has given to the writer most satisfactory results—first, as regards the life of the patient, and second, as regards the complete function of the joint. These rules are immediate asepsis of the entire limb; thorough irrigation of, and free drainage entirely through and across, the ankle-joint; the securing of perfect immobility with plaster of Paris; removal of the drainage-tube on the third day, with final irrigation and closure of the drainage openings; the employment of gentle passive movements and massage at the end of the third week; and the free use of the joint without crutches or cane at the end of the sixth week.

Any result other than one attended with no constitutional disturbance and with complete restoration of the joint may be called unsatisfactory. The adoption of merely one or several of these rules will not yield a good result. Their adoption from the beginning to the end in the order mentioned is necessary to secure a satisfactory result. Perfect asepsis at the start will not yield brilliant results unless faithful and conscientious attention is paid to the subsequent details. Each rule must be observed in proper sequence in order to obtain at the end of the treatment an ideal result.

Immediate Asepsis of the Entire Limb.—Too much importance cannot be placed upon this first rule. The extremity should immediately be thoroughly washed with an abundance of soap and warm water, protecting at the same time with iodoform gauze the opening into the joint during this ablution. The entire limb should be cleanly shaved with a razor and again washed, after which the parts should be freely irrigated with a 1 : 500 solution of bichloride of mercury. A saturated solution of iodoform in ether should be poured over all the limb. The part should now be protected with towels wrung out in a bichloride solution, 1 : 2000. Having removed the wet towels placed under the leg during the aseptic cleansing of the limb, and having substituted clean bichloride towels, attention is next directed to the joint itself.

Thorough Irrigation of the Joint.—An irrigator suspended a few feet above and filled with a hot 1 : 5000 bichloride solution should now be used. The nozzle of the syringe should be introduced into the joint and all the blood-clots washed out, together with débris that may have entered the joint. A strong director should be passed through the joint until its blunt end is felt at a point opposite, and then it should be cut down upon and the wound made large enough to admit a large-sized drainage-tube.

Surgeons have been accustomed to drain the joint upon one side, and introduce the tube at the opening made at the site of the injury. This is inadequate and insufficient. A pocket upon the opposite side of the joint is formed in which blood-serum, lymph, and synovia collect, and thus a nidus is formed for infection. Unless the joint is thoroughly irrigated in all its parts there is danger of abscess. If a study of compound dislocation of the ankle-joint is made, the interesting fact is observed that abscesses are subsequently formed upon the side of the joint directly opposite to the original opening. The time of formation of these abscesses, and their situation and character, point to the fact that

their development is due to sepsis originating within the joint. The curious clinical fact that some time after the original injury to the joint an abscess forms upon the opposite side, and where the tissues are all sound and uninjured, suggests at once that the abscess is due to sepsis and caused by the retention of septic material in the pocket of the joint distant from the original wound. By free and perfect drainage, by antiseptic irrigation at the time of the first dressing, and by providing a free outlet upon the healthy side of the joint, we may make sure that no retention of blood or lymph or synovia can take place, and wherever such perfect drainage is established the abscess is prevented. The abscess that forms under these circumstances is prolific of evil. It sets up free suppuration in the joint, and this is followed by necrosis, and then resection or amputation must be performed as a *dernier ressort* to save the patient's life.

The next rule to adopt in the management of these cases is the immediate fixation by plaster of Paris. Perfect immobility is essential, and this can be best secured by the employment of the plaster-of-Paris bandage. The wound having been covered by iodoform gauze, and pieces of wet bichloride gauze having been placed loosely over the wound and upon the foot and leg, a wet antiseptic bandage should be applied to keep the loose dressing in place. Over this a combined dressing or layers of purified cotton should be rolled, and a bandage to keep the dressing in place. A piece of sheet iron about one inch in breadth, and bent at the heel so as to extend from the toe down the plantar surface of the foot over the heel and up on the posterior surface of the leg, reaching above the knee-joint, should be adjusted. A corresponding strip of sheet iron bent to fit the dorsum of the foot, the front of the ankle, and the anterior surface of the leg should next be applied. Two short lateral splints of the same material should be placed on either side. The plaster-of Paris bandage can now be rolled over the splints, and a light plaster bandage applied, which now possesses great strength on account of the splints, but which is not heavy or cumbersome. At the first dressing a fenestrum can be cut over the wounds in order to withdraw the drainage-tube. The leg can be suspended by a Salter swing, which will enable the patient to move about in all directions in bed during the repair of the wound. If there is any difficulty in placing the foot and limb in proper position, the tendo Achillis can be divided, and thus physiological rest is at once enforced.

Still another rule refers to the time of removal of the drainage-tube. If the wound is small and there has been little laceration, the third day is the most appropriate time for the entire removal of the drainage-tube. If, however, there is an excess of discharge from it, the tube can be allowed to remain until the following day. At this dressing on the third day, if it is thought best, for the reasons given, not to remove the tube, then it should be irrigated, the nozzle of the syringe being introduced into one end of the tube, and a weak bichloride solution passed through it and through the joint, and the drainage made once more free.

It sometimes happens that after the joint has been irrigated the tube can be divided into two parts and a short end inserted into each of the bilateral wounds, and these left in until the following day. If the tubes remain longer than three or four days, they excite irritation in the joint

and may set up suppuration. Again, the rubber tubes become softened in three days, and are likely to tear apart, owing to the tension produced by withdrawing them through tissues to which they have become agglutinated by inflammatory adhesion. Finally, after three days the tubes, having accomplished the object for which they were employed, should be removed, because they are not intended to drain pus, but to carry off the products of acute inflammation arising from the traumatism to the joint.

The rule which relates to passive movements and massage at the end of the third week is an important one to observe. Any movement of the joint prior to this date is attended with danger. The parts are not ready for passive motion before three weeks, and an attempt to move the joint prior to that time will excite a new inflammation which may lead to suppuration. If the joint is not moved at this time, the adhesions become firm, and ankylosis is certain to follow, and consequently the function of the joint is destroyed. Shampooing aud gentle friction are also valuable adjuvants at this period in the history of the injury. It is to be especially noted that the movement allowed to the joint is not active, but passive, and the former should not be permitted until six weeks from the date of the accident. The rule that Sir James Paget has given is here especially applicable. He taught that an acutely-inflamed joint with heat and tenderness in it should be kept physiologically at rest, and that a joint that was stiff and partially ankylosed, but was free from all inflammatory action, should be treated by passive motion and massage.

The last rule refers to the time when the patient should begin active movement in the joint. Active motion in the joint is necessary at this period to excite the secretion of synovia, to release the tendons from any adhesions due to a thecal inflammation, to disintegrate fibrous adhesions, to restore the natural motion in the joint, and to absorb any of the products of inflammation or of collateral œdema and ecchymoses in the surrounding soft structures. It sometimes happens that at this stage swelling occurs in the leg or in the foot from the removal of the plaster bandage. This is, however, only temporary, and will soon disappear upon the patient walking about for a few days. If active motion is allowed earlier than the sixth week, there is danger of exciting new and suppurative inflammation in the joint, and a joint that gave every prospect of becoming perfect in function at the end of the second or third, or even the fourth, week may become totally destroyed by a too early employment of motion at a time when absolute rest is imperatively demanded.

No hard-and-fast rule can be made as to the amount of movement that the patient should be allowed to make. The best guide is the feelings of the patient. Too much exercise is as harmful as too little, and exercise attended with pain and fatigue is as injurious as movement of the joint a week after the injury. The patient should be advised to move the joint but little at first, and by increasing the amount of movement daily perfect restoration of the joint can be secured.

DISLOCATION OF THE ASTRAGALUS occurs as a result of falls from a height or of a sudden wrench or twist of the foot. In these injuries the ligaments are torn from their attachment, and the bone, being free, is thrust out of its position by the tibia, while the foot is strongly flexed,

extended, or inverted. The bone is dislocated from its relative position between the os calcis and the tibia and fibula. This injury must not be mistaken for dislocation of the ankle-joint, a description of which has already been given. In dislocation of the astragalus the bone not only is separated from the malleolar arch, but also from its attachments beneath to the bones of the tarsus. In dislocation of the ankle-joint the astragalus maintains its relative position to the bones of the tarsus.

The **varieties** are *forward*, *backward*, *outward*, or *inward*, and by *version*.

In the *forward* dislocation, which is the most frequent, the bone becomes displaced in consequence of a fall or by a twist of the foot, which is at the time of the accident in the position of full extension. The astragalus is thus thrown forward against the astragalo-scaphoid ligament, which gives way and permits the bone to be thrust out of its socket and become lodged just beneath the skin on the dorsum of the foot.

The **signs and symptoms** are the presence of the rounded head of the astragalus upon the dorsum of the foot, the disappearance of the normal landmarks of the joint, the complete loss of function, the shortening of the limb, owing to the position of the malleoli near the sole of the foot, the prominence of one malleolus and the obliteration of the other, with either inversion or eversion of the foot.

Dislocation of the astragalus backward occurs as a rare injury. In this variety the bone is forcibly driven backward and either outward or inward upon one or the other side of the tendo Achillis. The inferior surface of the bone lies upon the back part of the superior surface of the os calcis. This accident occurs when the foot is in extreme flexion, the reverse of the position when a forward dislocation occurs. The injury results from a severe twist or wrench which causes rupture of the posterior fibres of the deltoid and external lateral ligaments, as well as of the interosseous ligament.

The **signs and symptoms** are the presence of a bony prominence just above the heel, with the tendo Achillis stretched tightly over it upon one or the other side; a marked depression upon the front of the ankle-joint, with a prominent ridge above the fossa, consisting of the anterior articulating margin of the tibia; complete loss of function and marked flexion of the foot and immobility of the ankle-joint.

Dislocations of the astragalus outward and *inward* occur with equal frequency, although either variety is seldom observed. If the dislocation is complete, a fracture of the corresponding malleolus occurs, and the dislocation is thus complicated. This accident results from some severe violence or by a fall upon the side of the body when the foot is caught and held firmly within the tight grasp of some object while the person is in motion.

The **signs and symptoms** of lateral dislocation are—presence of a bony prominence upon one side of the foot, with a corresponding depression upon the opposite side of the joint; and crepitus, as a rule, since the malleolus upon the affected side is fractured.

Dislocation of the astragalus by version occurs from a sudden twist or wrench of the foot, and the bone may undergo rotation upon a horizontal or vertical axis. During the receipt of the injury the foot is

usually placed midway between flexion and extension, and consequently at a right angle to the leg.

The **signs and symptoms** are chiefly negative, since there are no characteristic changes which enable the surgeon to diagnosticate the precise nature of the injury. The diagnosis must be established upon the sudden loss of motion in the joint, severe pain increased by movement of the foot, a rapidly-occurring synovitis, partial loss of the normal contour of the joint, and, finally, the existence of a serious sudden joint affection, without any bony prominences to serve as a guide to determine the character of the injury.

The **treatment** of dislocation of the astragalus is complex, varying somewhat according to the special variety and the extent of damage inflicted. In the incomplete form the dislocation is easily reduced. In the complete form often great difficulty is met with in attempts to rectify the condition. In the *forward* variety continuous traction of the foot upon the leg must be made, with the knee flexed to relax the tendo Achillis. It is usually necessary to make this manipulation with the patient under the influence of an anæsthetic. If by flexion, extension, traction, and manipulation the bone cannot be returned to its proper place, the tendo Achillis and any other rigid tendon should be divided. Tenotomy usually permits the reduction of the dislocation. If, now, the surgeon is still unable to return the bone to its proper place, an incision should be made and the obstacles to reduction removed if possible. If this fails, the question of a primary resection, conservatism, or amputation arises. The operation of resection depends upon the constitution, age, and extent of damage to soft parts. If the patient is young or in adult life, with healthy viscera, and the astragalus is causing pressure enough to produce sloughing of the skin, a resection should be made, since with antiseptic surgery a primary resection is far better than to wait until abscesses form and extensive caries follows, which necessarily leads to secondary resection or amputation. If the dislocation can be partially reduced and movement in the joint is possible, and the patient is feeble or aged, conservatism should be the line of treatment. It is surprising how useful a joint can be secured in these cases under such conditions. If the dislocation is compound, the patient aged, and the soft parts are badly damaged, Syme's amputation is indicated. After reduction of a dislocation of the astragalus a plaster-of-Paris splint should be applied and the joint kept absolutely quiet for at least six weeks. If a resection is performed, the rules already given for resections should be adopted, and if amputation is required, the ordinary rules governing this operation should be observed.

Subastragaloid dislocation consists of a separation of the astragalus from the scaphoid and os calcis. In this dislocation the connection between the astragalus and the tibia and fibula is not disturbed.

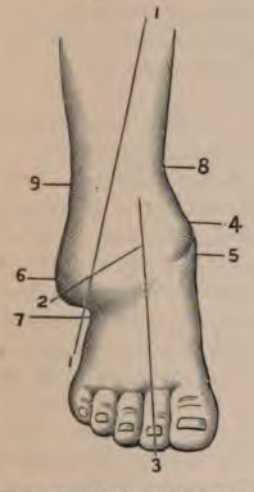
The **varieties** are *forward*, *backward*, *outward*, and *inward*. If the foot is dislocated *forward*, the head of the astragalus rests upon the calcanear facets; if *backward*, upon the dorsal surface of the scaphoid or cuboid bones; if *outward*, upon the cuboid bone; if *inward*, upon the tuberosity of the scaphoid bone (Fig. 171). These subastragaloid dislocations are caused by violent sprains or twists of the foot, and the ligaments connecting the astragalus with the scaphoid or os calcis tear,

while the ligaments between the astragalus and the tibia and fibula remain unbroken.

The **signs and symptoms** are extension of the foot, which is lengthened behind and shortened in front; prominence of the head of the astragalus, with the skin stretched tightly over it; eversion or inversion of the foot according to the special variety of the dislocation; and great prominence of one malleolus, with a partial obliteration of the prominence of the opposite malleolus and of the astragalus.

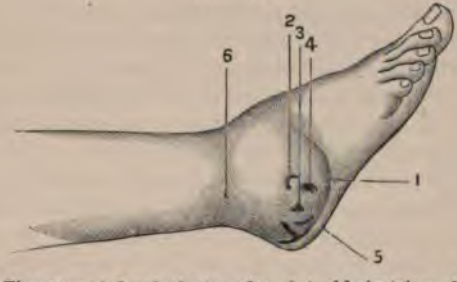
The **treatment** consists of extension of the foot while the knee is flexed, and manipulation of the tarsus during extension. The patient should be placed upon his back upon a table, and the leg held firmly down, while the foot hangs just over the edge of the table. If the tendons resist, they must be divided. After reduction the rules governing the management of dislocations in general should be strictly adhered to in every case.

FIG. 171.



Subastragaloid dislocation inward: 5, sustentaculum tali; 4, inner malleolus (Du Bourg).

FIG. 172.



The same: 1, head of astragalus; 3, 4, old cicatrices; 5, a fistula; 6, fracture of the fibula (Du Bourg).

In *compound subastragaloid* dislocation a primary resection offers the best chance for the recovery of the patient and for the future usefulness of the joint. If the bone projects and its ligamentous attachments are torn, the bone is likely to become carious, which eventually leads to a secondary resection, and the results obtained under these conditions are not so advantageous as those from a primary resection under improved antiseptic methods.

Dislocation of the medio-tarsal bones is occasionally observed. The os calcis, scaphoid, cuboid, and the cuneiform bones have all been dislocated, either alone or in conjunction with each other, and generally such dislocation is associated with a fracture.

The **signs and symptoms** are the presence of a dorsal bony prominence, a depression corresponding to the situation of the bone, and obliteration of the plantar arch of the foot.

The **treatment** consists in traction of the anterior part of the foot while the heel is held firmly, and digital pressure to push the bone into its normal place. In uncomplicated cases reduction has usually been effected. In compound dislocation of the medio-tarsal bones the extended bone should be removed if the skin is badly damaged and the

bone is free from its ligamentous attachments; otherwise caries of these articulations is likely to follow and necessitate a secondary resection or amputation, the ultimate result of which is not so favorable as is that of a primary excision of the displaced bone under strict asepsis.

DISLOCATION OF THE METATARSAL BONES may occur as a result of a fall from a height in which the patient strikes upon his foot, or by a heavy weight falling directly upon the dorsum of the foot, and in exceptional cases even by muscular action. The first metatarsal bone is more frequently dislocated than the second. The third, fourth, and fifth are usually dislocated together, rather than singly. In some cases all of the metatarsal bones have been simultaneously dislocated.

The **signs and symptoms** are too apparent to require any special description, since the character of the injury is at once recognized.

The **treatment** consists in traction of the toes while the heel is held firmly and manipulative pressure exercised. If this fails, the bone can be cut down upon and forced into its position. As a rule, reduction is most easily accomplished. In those few cases where failure to reduce the bone was reported the foot was fairly useful, notwithstanding the unreduced dislocation. In *compound* dislocation with extensive bruising of the soft parts, and with the ligaments badly torn, a primary resection of the bone is indicated, and in only very exceptional cases would an amputation be performed.

DISLOCATION OF THE PHALANGES is not often observed. The dislocation occurs as a result of a fall upon the toes or by direct violence, as in kicking some object or stubbing the toe against a stone. The great toe is more often the seat of dislocation than the others.

The **signs and symptoms** are too apparent to need any description.

The **treatment** consists in traction of the dislocated toe while the foot is held firmly by an assistant. If the reduction cannot be effected in this way, some form of traction forceps, such as are used in case of dislocation of the thumb, can be employed. If this manipulation fails, the bone can be cut down upon and another attempt made, and in case of repeated failure a primary excision of the phalanx should be performed, or even an amputation of the toe, especially if it is any other than the great toe.

ANÆSTHESIA.

By H. C. WOOD, M. D., LL. D.

In considering the subject of anæsthesia the first question which arises is as to the choice of the anæsthetic, and in discussing this it seems to me important to call attention briefly, but emphatically, to the relations which ought to exist between clinical and experimental medicine. The value of experimental medicine to the profession is very great, but it is entirely possible to go wrong in the practice of medicine by attaching too much weight, or rather by attaching improper weight, to the apparent results of experiments. The ultimate appeal for a final decision in therapeutics must always be to clinical medicine. Experiments upon the lower animals are sometimes useful as guides in making experiments upon human beings, but their chief value is to be found in the interpretation of the results reached at the bedside. So much attention has been in the past few years given to the experimental study of anæsthetics that there has been danger of undervaluing the clinical side of the subject. In the present article it is proposed to consider first the clinical, second the experimental, evidence.

In the selection of an anæsthetic the question of safety is paramount. One anæsthetic may be more convenient than another, less disagreeable to the patient, less costly in time to the surgeon; but the question of safety should dominate all others. It should never be forgotten that at present we know of no true anæsthetic (for nitrous oxide, for reasons given hereafter, scarcely belongs to the class) whose use is unaccompanied with danger. It is true that recent, and perhaps even the older, medical literature is flecked with the assertions of various surgeons that not only have they given anæsthetics many hundreds of thousands of times without accident, but also that these results have been due to their own individual skill, and that if their methods of administration were adhered to all the danger of anæsthesia would be overcome.

There are few things more tiresome in medical literature than these clamorous outcries of conceit and vanity. The surgeon who claims that in his hands anæsthetics are free from danger, forgetful that death from anæsthesia has occurred in the practice of Simpson, Symes, Gross, Agnew, Billroth, and almost the whole of the list of the world's greatest of surgeons, causes in us some amusement, and still more disgust. Anæsthesia produced in any way is a condition of danger, and the one great hope of safety on the part of the patient lies in the recognition of this fact by the anæsthetizer. Despite all precautions, given so many thousand anæsthesias there will be so many deaths from the anæsthetic; the only hope is by careful study and by careful administration to reduce the mortality

to the minimum : the unexpected will in all probability sometimes happen to the end of time.

These things being so, the first matter to be decided is what the clinical records reveal as to the comparative frequency of the deaths from the various anæsthetics. Fortunately for our purpose, there have been recently published several elaborate studies of these records—studies so complete that reliance upon them is justifiable and further examination of the original records almost a waste of time. The number of substances which have been used by the surgeon to produce unconsciousness is quite large, yet three anæsthetics—nitrous oxide, ether, and chloroform—stand out before all others so prominently that I shall first study their comparative safety and use, afterward calling attention to some of the minor anæsthetics as a separate group.

In viewing any subject statistically there is always danger of being misled by fallacies which are too commonly recognized to be here dwelt upon in detail. There are two ways in which these fallacies may be more or less completely avoided : first, by the selection of a comparatively small cluster of observations made by a single individual or a small group of individuals under circumstances as nearly uniform as may be ; second, by the gathering together of an immense number of statistics, made under all conceivable circumstances by all sorts of observers—a collection in which the mass is so large that there is hope that mistakes in one direction may be counterbalanced by mistakes in the other. The best recent example of the first method applied to anæsthesia with which I am familiar is in the table compiled from the St. Bartholomew Hospital Reports by Dr. Geo. M. Gould, editor of the *Medical News* of Philadelphia. From 1875 to 1890, inclusive, in the St. Bartholomew Hospital anæsthesia was produced 19,526 times by chloroform, 8491 times by ether, and 12,941 times by ether preceded by nitrous oxide. The number of deaths were respectively 13, 3, 1, giving the mortality of chloroform as 1 in 1502, ether as 1 in 2830, and ether preceded by nitrous oxide as 1 in 12,941.

Of statistics in which it has been attempted to avoid error by mass the most recent and probably the best is the table prepared by Dr. Gould based upon that published by Julliard, who in turn used that of Compte as a foundation. In this table there are included 638,461 administrations of chloroform, with a total of 170 deaths ; 300,157 administrations of ether, with a total of 18 deaths, giving a mortality of chloroform anæsthesia as 1 in 3749, and ether anæsthesia as 1 in 16,675.

The probable correctness of the conclusions reached by the Gould-Julliard-Compte statistics is strongly confirmed by the closeness with which the results coincide with those obtained from other large statistics. Many years ago Dr. Richardson of London placed the probable number of deaths from chloroform as 1 in 3000. In a careful discussion of the statistics of anæsthesia Dr. H. M. Lyman reached the conclusion that the proportion of chloroform deaths is 1 in 5860. In the proceedings of the German Surgical Society in Berlin, 1891, sixty-six European surgeons reported nearly 23,000 cases of chloroformization, with 6 deaths, giving a proportion of 1 in 3776.

In the report of the *Lancet* Commission for the clinical study of anæsthetics it is attempted to get at the proportionate number of deaths by

estimating the probable total number of anæsthesias and the total number of reported deaths. The difficulty with this method is obvious: only a portion of the anæsthetic deaths are reported, and the estimation of the number of inhalations is nothing else than guesswork. The conclusion reached by the commission is that there have been thirteen times as many deaths from chloroform as from ether, and that the number of inhalations of chloroform has been six times as great as those of ether; which gives a mortality-rate to chloroform more than double that of ether. These results correspond with the statistics of the St. Bartholomew Hospital, but are very much more favorable to chloroform than are the conclusions to be drawn from the large mass of statistics, which mass gives the proportionate mortality about as four and a half to one. I personally believe that the large statistics, overwhelming as they are in the number of cases reported, represent as near as can be the true state of the case, and that the surgeon who administers chloroform faces the fact that the dangers of its use are more than four times those which confront the man who administers ether.

In strong contrast to the clinical results of the use of chloroform and ether is the history of nitrous-oxide inhalation. The *Lancet* Commission has collected seventeen deaths as having occurred during the anæsthetic use of the gas: several of these cases are, however, not fairly attributable to the inhalation, but even if they all be accepted as accurate reports, the mortality is scarcely more than nominal. The gas is probably administered to seven or eight hundred thousand people annually by lecturers, dentists, etc., some of them men of education, others men of ignorance. In other words, many millions of inhalations have been given, many of them by incompetent persons, and yet less than two dozen cases of death have occurred during the decades since the first administration of the gas. Dr. Chas. M. Buchanan[1] is probably not far out of the way in his conclusion that the mortality of nitrous-oxide inhalation is 2 in 10,500,000.

The startling difference between nitrous oxide and the other agents used leads naturally to a search for causes. The reason of the difference is that nitrous oxide lies apart from other anæsthetic agents in being an inert substance so far as the human organization is concerned. In the production of anæsthesia it acts by shutting off the oxygen from the blood, as is shown by the fact—established by Jolyet and Blanche, by Elihu Thompson, and by my own experiments—that an animal will live in nitrogen, in hydrogen, or even in a vacuum, as long as in pure nitrous oxide; and that, as shown by myself,[2] the circulatory phenomena of nitrous-oxide anæsthesia are very similar to those which are caused by the inhalation of pure nitrogen or by mechanical asphyxia; that, as demonstrated by the French observers, coma is not developed until the oxygen in the blood is reduced to 3 or 4 per cent.; that, as proven by my own experiments,[3] the time required for the production of anæsthesia is practically the same with nitrous oxide as with mechanical asphyxia; and finally, as was shown in my own experiments, that the addition of 3 per cent. of oxygen doubles the time necessary for the production of anæsthesia, whilst the addition of 5 per cent. of oxygen more than

[1] *Medical News*, vol. lxii., 1893.

[2] *Therap. Gaz.*, 1890.

[3] *Dental Cosmos*, 1893.

sextuples the time required, and 8 per cent. of oxygen indefinitely postpones the production of complete anæsthesia, at least in the dog.

During the use of the true anæsthetic there is a poison circulating in the blood, and when an accident occurs time is required for the removal of this poison even if no more of the anæsthetic be administered. In nitrous-oxide anæsthesia there is no poison in the blood, and if at any time the partial arrest of function which has been produced by shutting off the sustaining oxygen becomes too complete, the introduction of oxygen into the blood finds the nerve-centres ready at once to respond to their natural stimulus. Unfortunately, the brevity of the action of nitrous oxide prevents its general use for the purposes of the operating surgeon. When, however, a tooth is to be drawn, an abscess to be opened, or other surgical procedure involving but a moment of time gone through, nitrous oxide is the safest and best of known anæsthetics.

The second sub-question which presents itself for study is as to the method in which anæsthetics produce death; and here, again, the profession is under great obligation to the *Lancet* Commission for the extraordinary labor with which it has searched out clinical records. It has analyzed and tabulated the reports of 384 deaths during chloroformization, and has shown that out of this number in 227 cases the pulse failed entirely before the cessation of respiration; that 77 times cardiac and respiratory action ceased simultaneously; and that only in 80 cases did respiration stop before the heart.

Whatever the results of experimentation with anæsthetics upon the lower animals may be, it seems to me absurd for any one to claim that in man chloroform does not frequently produce death by an action upon the heart. In numerous cases of chloroformization the action of the heart has been tested not only by feeling the pulse, but also by auscultation—tested, too, with a full knowledge on the part of the observer that leaders of the profession have declared that chloroform never kills by its action upon the heart; and yet in nearly four cases out of five it has been noted that the death came through the heart. If clinical observations upon the simplest questions be of any value whatever, the conclusion must be that in the large majority of cases chloroform death has been due to cardiac arrest. It must be remembered that the average intelligence and skill of the surgical observers who have recorded fatal accidents from anæsthesia is simply the general average intelligence and skill of the surgical profession; and if these gentlemen are not to be trusted to observe such patent phenomena as indicate a cessation of circulation or of respiration, to whom are we to look for such data?

All observers, clinical and experimental, are in accord in acknowledging that when chloroform paralyzes the respiration it does so by a direct action upon the respiratory centre; the matter still requiring careful discussion is as to the way of the syncopal deaths.

When chloroform is given to the lower animals there is always after the first half minute of the inhalation a progressive lowering of the arterial pressure. Up to this point there seems to be no discordancy, and in the controversy which has raged for the last few years on the subject we get one firm, indisputable point—namely, that *ether is a stimulant* and *chloroform a depressant to the circulation*. For many years all observers have agreed that chloroform directly lowers the arte-

rial pressure, but great has been and still is the dispute as to the immediate mechanism of the fall which the drug produces. Does the pressure come down through the widening of the blood-paths by a centric or vasomotor paralysis, or is the fall in part or altogether due to an action upon the heart? In other words, is chloroform a vasomotor depressant simply, or is it also a cardiac depressant?

Sansom and Harley state that during chloroformization a spasm of the small vessels can be readily seen to occur in the web of the frog. Not until the third stage is reached, according to these authors, do the vessels relax into dilatation. If these observations be correct, chloroform first stimulates and afterward depresses the vasomotor centres. In accordance with this are the experiments of Gaskell and Shore,[1] who find that the local application of chloroform to the medulla or its injection into the cerebral artery produces an immediate rise of blood-pressure, usually accompanied by a slowing of the heart, this rise being followed by a fall of pressure so soon as the chloroform is able to diffuse itself over the circulation. In a further very ingenious series of experiments, Gaskell and Shore connected the carotid arteries and jugular vein of an animal (A) with the similar vessels of the second animal (B), so that the brain of A was fed exclusively with blood from B. It is plain that chloroform given to B would reach the brain of A, but would not reach the heart of A. Under these circumstances it was found that chloroform administered to B produced rise of pressure in A. In a second series of experiments the blood-vessels of A were so connected with those of B that when chloroform was administered to B it reached the heart of A and all other portions of the body except the brain. When this was the case, chloroform given to B produced an immediate fall of arterial pressure in A, without any previous rise. In other words, when chloroform reached the vasomotor centres, and not the heart, it caused rise of arterial pressure; when it reached the heart, and not the vasomotor centres, it caused fall of pressure.

The only experiments with which I am acquainted to which any weight should be attached as indicating that chloroform primarily paralyzes the vasomotor centres are those published as long ago as 1874 by H. P. Bowditch and C. S. Minot.[2] In these experiments, which were made upon curarized animals, "irritation of the saphena nerve caused a much less marked rise of blood-tension than when the anæsthetic was not used. Sometimes there was absolutely no rise of tension to be observed, while at other times the rise was from one-third to one-half that produced by the same irritation on an animal not subjected to the action of chloroform." Further, compression of the carotid in the chloroformed animal did not cause the customary spasm and rise of arterial pressure.

It must be remembered that these experiments of Bowditch and Minot were made at a time when the importance of the subject had not been fully realized; that on the carotid but a single experiment was made; and that there was frequently in the experiments of Bowditch and Minot a great rise of pressure following irritation of the sensitive nerve, though the rise was not as great as in the normal dog. There seems to be no doubt that late in chloroform-poisoning there is vaso-

[1] *British Med. Journ.*, vol. i., 1893. [2] *Boston Med. and Surg. Journ.*, 1874.

motor paralysis, and it may very well be that in the single carotid experiment of Bowditch and Minot the chloroformization had been carried on to the fullest extent, whilst the rise of pressure which occurred in many of their chloroformed dogs when the saphena nerve was irritated shows that at such times, at least, the vasomotor centres were not paralyzed, though the arterial pressure had fallen very distinctly. The results, therefore, of Bowditch and Minot are not in any way proof of the incorrectness of the theory of Gaskell and Shore, and the drift of the present evidence is to show that *chloroform in the earliest stages of its action stimulates rather than depresses the vasomotor centres.*

On the heart itself chloroform undoubtedly exerts a steady, powerful depressing influence. Injected into the jugular vein (see also MacWilliam's experiments), it instantly arrests the heart's action and destroys its muscular irritability. Even the vapor of chloroform, when locally applied to the exposed heart, paralyzes it.[1] When artificial respiration is maintained the effect of chloroform upon the heart is very apparent.[2] By a very ingenious series of experiments Dr. MacWilliam[3] has proven that very early in chloroform anæsthesia there is a marked diminution of the force of the auricular and the ventricular beats, accompanied with dilatation of the cardiac chambers, due to the direct influence of the chloroform. Again, as pointed out in the paper of Gaskell and Shore, even the tracings of the Hyderabad Commission show that from the very beginning of chloroformization the excursions of the heart-beat, as portrayed by the Fick manometer, get smaller and smaller in the most typical manner. Indeed, as Gaskell and Shore say, "every one would agree with the commission that they (the pulse-waves) are of the typical kind which would be produced if direct weakening of the heart were the cause of the fall of blood-pressure in chloroform administration."

Putting all the evidence together, it seems to me to have been completely demonstrated by physiologists—first, that *chloroform is a direct depressant and paralyzant to the heart-muscle or its contained ganglia;* second, that *the early fall of blood-pressure which occurs in chloroformization is in great part, if not altogether, due to this direct depression of the heart.*

This conclusion having been reached, attention is next naturally directed toward a study of the action of ether upon the circulation.

It is firmly established by the coinciding results of very many experiments performed by various observers that during etherization there is usually a pronounced rise in the arterial pressure, which is commonly maintained even through a prolonged narcosis, and may continue after manifest failure of respiration. Sooner or later, if the inhalation be continued, the rise of arterial pressure is followed by a fall, which may progressively increase until the manometrical needle reaches almost zero. There have been very few careful studies of the details of the action of ether upon the circulation, but such facts as we have go to show that the primary influence of the drug is to stimulate both vasomotor centres and heart, and that during the stage of low pressure there is depression of the vasomotor centres and also of the heart. The

[1] *Edinburgh Med. Journ.*, 1842. [2] *Journ. Anat. and Physiol.*, xiii., 226.
[3] *British Med. Journ.*, vol. iii., 1890.

belief in the primary stimulation of the vasomotor centres rests almost entirely upon the research of Professors Bowditch and Minot, made in 1874, and the subject is well worthy of a careful re-study. There is much reason for the belief that in advanced and profound ether-narcosis the blood-vessels are affected by the direct action of the substance upon their coats.

The clinical and physiological facts which have thus far been brought forward in this paper would seem in themselves, and in their accordance, sufficient to prove that fatal syncope by direct effect of chloroform upon the heart is the common cause of chloroform death, and that ether is the safer remedy, because it usually primarily stimulates the heart. The matter is not, however, quite so clear as it seems. It has been within the last few years repeatedly asserted by physiologists of repute that neither ether nor yet chloroform ever kills the lower animal by cardiac paralysis; or, in other words, that it is not possible to produce in the lower animals by inhalation of ether or chloroform arrest of the heart's action before arrest of respiration. This is, however, an error. I have been seeing chloroform death in animals with great frequency for nearly twenty-five years in the physiological laboratory, and I have made a large number of experiments in the most careful manner, and I know that in the dog chloroform may produce death by a centric respiratory paralysis, but more commonly in my experiments has there been a simultaneous or almost simultaneous arrest of respiration and circulation, and occasionally, and as a rare phenomenon, primary arrest of the heart has occurred. I have seen the respirations continue for fully two minutes, much of the time full and fairly frequent, although there was no blood-movement whatever in an exposed carotid artery or any movement of the heart that could be detected by the hand or ear.

Again, in exceptional cases the stimulant influence of ether upon the circulation is very slight and transient, so that in the physiological laboratory I have seen the blood-pressure begin to fall during an early stage of ether anæsthesia, and I have in one or two cases seen a cardiac arrest produced by ether at a time when the respiratory function was still active. As every one knows, the Hyderabad Commission, the great supporter of the exclusiveness of respiratory death, derived most of its authority from the presence on it of Lauder Brunton of London, who in a recent publication says: "If we drive chloroform into the trachea, or air very heavily loaded with chloroform vapor into the lungs by artificial respiration, it will be absorbed in sufficient quantities to paralyze the heart." This is a practical giving away of the whole case of the Hyderabad Commission, at least as I have understood it, and as I believe it to have been understood by the general profession. However this may be, it is a confession that the chloroform death is not of necessity due to asphyxia, so that it must be admitted, first, that both ether and chloroform may kill the man or the lower mammal either by arrest of respiration or by syncope; second, that syncopal death from chloroform is not common, though it does occur in the lower animals, but is not rare in man; third, that the chief difference between ether and chloroform, so far as the mode of death is concerned, is that that form of death (syncopal) which is common under the influence of chloroform is rare under the influence of ether.

The cardiac action of chloroform is evidently one cause of the greater fatality of chloroformization, but it is not the only reason why chloroform kills so much more frequently than does ether. In my experiments upon the lower animals I have noted that chloroform lets go its hold much less readily than does ether. This, I had always supposed, was simply due to the greater volatility of ether, but a recent very interesting research by Mr. Julius Pohl seems to show that chloroform has a primary attachment, so to speak, for the brain—*i. e.* a tendency to accumulation in the brain-tissues. Mr. Pohl found on chemical examination that there was much more chloroform present in the brain-tissues than in the blood passing to the brain—a fact to be explained only as a result of storing up in the brain. It may well be that one cause of the persistency of the action of chloroform upon the nerve-centres is due to this tendency to escape from the blood-vessels into the nerve-tissues. Nevertheless, the comparative volatility of the two anæsthetics and the comparative diffusibility of their vapors appear to be distinct elements in the comparative danger of their use. There is very great reason for believing that chloroform is less lethal in hot climates than in colder regions. The British surgeons of India aver with one voice that they can administer it without evil effect. The anæsthetizers of the extreme southern or Gulf tier of American States are almost equally urgent in claiming safety for the use of chloroform, whilst on the continent of South America it is solely employed, again with alleged freedom from ill effect. The only explanation of these facts which seems to me plausible is that at high temperatures chloroform vapor diffuses very rapidly, and consequently escapes from the blood and from the lungs with extraordinary rapidity.

So far as concerns what may be considered the major anæsthetics, the question asked in the beginning of this essay has now been answered; the answer being—first, that nitrous oxide is the safest and best of the anæsthetics when the purposes of the anæsthesia admit of its use—that is, when the anæsthesia needs only to be of short duration; second, that both clinical and experimental evidence agree in showing that ether is much safer than chloroform, and, as safety is under ordinary circumstances the one quality that the surgeon should consult in the choice of an anæsthetic, no surgeon is justified in employing chloroform unless it be under certain peculiar circumstances and for certain definite reasons or purposes.

Having arrived thus far, the next question naturally is, What are the circumstances which justify the use of chloroform?

Before, however, discussing this it seems but right to consider the possibility of substituting for chloroform and ether some other anæsthetic. This leads, in turn, to the study of what may be termed the *minor anæsthetics*.

Of the numerous substances which have been more or less clamorously put forward as valuable anæsthetics, but few require notice here.

Bichloride of methylene was originally highly recommended by Dr. B. W. Richardson in 1867, and gave rise to a considerable controversy. In 1883, MM. Regnauld and Villejeau obtained directly, through agents accredited by Sir Spencer Wells, the great advocate for the use of methylene bichloride, the article employed as the bichloride in England. On

careful chemical study they found that it contained no bichloride of methylene, but was composed of four parts of chloroform and one part of methylic alcohol. About this time, without knowing anything of this work, I had a bichloride of methylene of a leading London chemist examined in the chemical laboratory of the University of Pennsylvania, and found that it was almost pure chloroform; so that there can be no doubt that commercial bichloride of methylene has been generally a more or less impure chloroform.

In the further studies of Regnauld and Villejeau it was determined that chemically-pure methylene bichloride is very difficult and costly of preparation, and that when it is given to the lower animals as an anæsthetic it produces not a quiet anæsthesia, but choreic movements and epileptiform convulsions. There are on record at least nine deaths produced by the commercial drug, and it does not seem necessary further to discuss the matter here; the bichloride of methylene must be dismissed from the list of practical anæsthetics.

Pental, a very recent candidate for professional favor, is a colorless, highly inflammable liquid, boiling at 100.4° F., which when administered produces with extraordinary promptness a narcosis which is said to disappear more rapidly than does that caused by chloroform or ether, but less rapidly than does that produced by ethyl bromide. In a study of the drug made by Dr. David Cerna and myself it was found that pental anæsthesia in the dog is always accompanied by a very pronounced fall of the arterial pressure, and the conclusion was reached that the remedy is a powerful depressant to the heart. Further, it has been noted by Kleindienst that in man three or four days after pental narcosis the urine very frequently becomes heavily charged with albumin, and that not rarely hæmaturia or hæmoglobinuria occurs. This, if confirmed, should put an end to any anæsthetic use of pental. Finally, according to the only statistics upon the subject that I know of—namely, those of Gurlt—pental would appear to be the most dangerous of all the anæsthetics in its action, there having been three deaths in the six hundred reported narcoses. The future does not look bright for pental.

Ethyl bromide is a colorless, very volatile liquid, which has been confounded with ethylene bromide with fatal results. The substances are essentially different, chemically as well as physiologically. Ethyl bromide does not solidify at 32° F., and has a specific gravity of about 1.49; ethylene bromide has a specific gravity of 2.16, and at 32° F. solidifies into a crystalline mass. Ethyl bromide was first proposed as an anæsthetic by Dr. Thomas Nunnelly in 1849, but was not brought earnestly before the profession until 1876–77, when attention was called to it by Rabuteau in France and Lawrence Turnbull in the United States. Its influence is usually manifested a few seconds after the beginning of an inhalation, and lasts from one and a half to three minutes after the removal of the drug from the mouth. A peculiarity that has been noted by several observers is a tendency for sensibility to be lost before consciousness is completely destroyed, and Professor Montgomery has especially noted that during parturition it will do away with most of the suffering without arresting the pains or producing complete unconsciousness. The narcosis is only in rare instances accompanied by complete relaxation of the muscles; indeed, it appears to be common for the

general muscular tonus to be greatly increased. According to Professor John H. Brinton, muscular rigidity, local spasms, and even general tetanus with opisthotonos, occur so frequently as seriously to interfere with the employment of the drug as an anæsthetic, especially as this condition of muscular excitement, when it develops during a surgical operation, is attended by great increase of hemorrhage.[1] During narcosis the corneal and pupillary reflexes are usually preserved, and the eyes are sometimes wide open and crossed from contractions of their muscles.[2]

The physiological action of ethyl bromide has been studied by Schneider, by Abonyi, by Thornton and Maxwell,[3] and by myself. Schneider states that the arterial pressure does not fall until very late in the bromide narcosis, and that death takes place always through arrest of the respiration. In these statements he is in accord with results obtained by Abonyi,[4] who was not able to detect any alteration in the beat of the exposed heart of the frog in which narcosis was produced. On the other hand, the experiments of Thornton and Maxwell are in agreement with my own, in showing that the arterial pressure falls early and increases steadily with a persistent inhalation. In my own experiments ethyl bromide seemed to act on the circulation similarly to chloroform, although less powerfully.

It is possible that the difference of result obtained by physiologists has depended upon the ethyl bromide being impure. In the eighth edition of my *Treatise on Therapeutics* it was stated that clinical results would probably show that ethyl bromide is a very dangerous anæsthetic, at the time of issue of the work there being three deaths reported as occurring in a very limited number of administrations.[5] To these cases must be added the death reported by Dr. A. Gleich,[6] also that recorded by Dr. Reich. On the other hand, Dr. Gilles claims[7] that there were given in Germany during three years twenty thousand administrations without a single fatal result, and that there is no fatal result on record in which it has been proven that a chemically-pure bromide has been administered.

This statement is, however, at present not correct. 16 cases of death from the ethyl bromide have been collected by Dr. Reich,[8] and of these in 5 the bromide is asserted to have been pure. It is remarkable that out of the 7 cases in which any information as to the time of death is given, in only 2 did death take place during the narcosis; in the other 5 cases it occurred from one to three days after. In Dr. Reich's case[9] the inhalation of the bromide was followed by immediate and continuous vomiting, with development of symptoms similar to those of acute phosphorus-poisoning, ending in death on the seventh day. At the autopsy the liver and kidneys were found in active fatty degeneration. After the inhalation it was remembered that the bromide used had a faint yellow color, and it may possibly be, therefore, that the fatal result was produced by some decomposition-product. Early in the

[1] *Therap. Gaz.*, viii.
[2] Dr. Gilles: *Berlin. klin. Wochensch.*, xxix., 1892.
[3] *Therap. Gaz.*, 1892.
[4] *Wiener Klinik.*, 1891, Heft 1.
[5] *Therap. Monatsh.*, vol. ii., 1888; and Turnbull's *Anæsthesia.*
[6] *Wien. klin. Wochensch.*, vol. v., 1892.
[7] *Berlin. klin. Wochensch.*, vol. xxix., 1892.
[8] *Wien. med. Wochensch.*, 1893, p. 1179.
[9] *Op. cit.*, p. 1226.

present year Kochler reported a case[1] in which the anæsthetic was given in small quantities with a mask, and in which, after a very transient and mild stage of excitement, the heart's action suddenly ceased and could not be restored, although the breathing is said to have continued for a long time. At the autopsy the muscular structure of the heart was found in a condition of extreme fatty degeneration.

Our present clinical experience certainly indicates that the use of ethyl bromide is not devoid of danger, but there seems to be no sufficient reason for believing that with an absolutely pure article the danger is greater than with chloroform. The brevity of the narcosis and the great muscular excitement which the bromide is apt to provoke stand greatly in the way of its general use as an anæsthetic, though they especially fit it for employment on certain occasions. It seems probable, also, that it will be found to be a successful practice to give the ethyl bromide at the beginning of an anæsthesia which is to be maintained by the use of ether. There are certain persons, especially alcoholics, who greatly resist ethyl bromide, and various surgeons strenuously assert that under these circumstances no attempt should be made to force anæsthesia by this agent, but that chloroform or ether should at once be substituted.

The best method of administering ethyl bromide appears to be to place about two drachms in an Allis inhaler or upon the cone-shaped napkin.

MIXED ANÆSTHETICS.—Various mixtures of chloroform and ether or alcohol, chloroform, and ether (the latter the famous A. C. E. mixture) have been employed by surgeons with results which have been on the whole unsatisfactory. These unsatisfactory results are probably, at least in part, dependent upon the different volatility of the different agents, making it impossible to know exactly what vapors are contained in the air breathed by the patient. All these mixtures are, in my opinion, more dangerous than the individual drugs of which they are composed, and their use should be eschewed. The method of producing anæsthesia with one agent and continuing it with another is entirely different from that which uses throughout a mixture of the two agents, and at present writing there seems to be reason to commend this form of mixed anæsthesia. Thus, it is probable that many of the difficulties which attend the use of ether can be overcome by putting in the inhaler or on the sponge ethyl bromide and then ether, the patient passing insensibly from the bromide narcosis into that of ether. In England it seems to be a not rare practice to commence anæsthetization with nitrous oxide and to continue it with the use of ether, and, if the statistics given by Dr. George Gould are correct, this method of anæsthetization would seem to be the safest known, for in 12,941 anæsthesias so produced in the clinic of St. Bartholomew's Hospital there has been 1 death. Certainly by the primary use of nitrous oxide the feelings of the patient and the time of the surgeon are spared.

CIRCUMSTANCES WHICH MODIFY THE CHOICE OF ANÆSTHETIC.

In answering the inquiry as to the circumstances which should modify the choice of the anæsthetic by the surgeon I shall first consider those

[1] *Centralbl. f. Chir.*, 2, 1894.

modifying circumstances which are simplest and least doubtful, and shall arrange the matter under enumerated heads.

First. When circumstances make it practically impossible to obtain the bulkier anæsthetic. Thus in war-times the difficulties of transportation, determining as they do the movements of great armies and the results of great national upheavals, may make it practically impossible for the surgeon to have choice, and certainly under such circumstances it is better to use chloroform than to do without anæsthetics.

Second. When the symptoms themselves are of such character as to immediately threaten life, especially if they at the same time interfere with the entrance of the anæsthetic into the lungs, the use of chloroform may well be justified. Thus, when a tetanus spasm locks the chest-walls it often would be folly to wait for the action of ether, and yet it must be remembered that under just such circumstances chloroform has apparently destroyed life.

Perhaps under this heading the use of chloroform during parturition should be alluded to. It has been stated from time to time by various writers that the excitement of labor in some way guarantees the system against the deleterious influences of chloroform, and that it may be used with impunity. This is not correct: death has occurred from the anæsthetic use of chloroform during parturition. Only infrequent occurrences in parturition make it necessary to use chloroform. Ether commonly acts with sufficient promptness, and should therefore be preferred. In a violent case of puerperal convulsions, however, and in other critical conditions, chloroform may be superior to ether. The known action of ethyl bromide gives great force to the statements of Professor Montgomery, that it is especially valuable during labor, and further trial of the agent seems to be demanded. The obstetrician, however, should exert extraordinary care to see that he has a pure specimen of the drug.

Third. There are certain bodily conditions, hardly to be spoken of as disease, which would exert some influence in the selection of the anæsthetic. In his recent book Dr. Frederic W. Hewitt states that old persons whose chests have become rigid seem not to be able to respond sufficiently to the demand made upon them by ether, and that very old persons bear chloroform practically well. In applying such a principle as this it must be remembered that it is not the years of the person, but the extent of senile changes in his tissues, which should influence the anæsthetizer. Dr. Hewitt recommends in such cases the A. C. E. mixture; if such mixture be employed, it should always be freshly made at the time of its administration.

Extreme obesity is another bodily condition in which it is affirmed that ether is often not well borne, producing so much excitement and respiratory irritation as to forbid its use. Under these circumstances again Hewitt recommends the A. C. E. mixture, but states that there are certain cases in which chloroform is necessary in order to secure sufficient tranquillity of breathing. I have not had practical experience with such patients of sufficient amount to be weighty, but my feeling is that in such cases ether should be first tried, and then, if it be not well borne, chloroform substituted, ether being again employed when quiet anæsthesia has been thoroughly established.

Fourth. Various diseases contraindicate the use of an anæsthetic, and also modify the proper choice of the surgeon, and I shall therefore under the present heading consider diseases as general contraindications to anæsthetics and also as modifying the selection by the surgeon.

The diseases which are generally thought to more or less positively contraindicate the use of anæsthetics are Organic Brain Disease, including Tumors; Atheromatous Conditions of the Vessels; Diseases of the Heart; Diseases of the Lungs; and Diseases of the Kidneys.

BRAIN.—It appears from the recorded accidents of anæsthesia that the existence of brain tumor and other organic forms of brain disease is more often the cause of death than are affections of the heart. When the brain-arteries are believed to be atheromatous, although no positive signs of organic brain disease are present, anæsthesia should be induced by the surgeon with the greatest reluctance. The cause of the extreme danger in these cases is probably the ease with which congestions are developed in a brain which is abnormal, and the loss of resisting power in the respiratory centres when weakened by disease. I know of no clinical data which will enable us to decide which is the safer agent, chloroform or ether, in the class of cases now under consideration. The greater power, however, of chloroform and the greater permanency of its influence would make it, *a priori*, probable that ether would be the less dangerous of the two.

HEART AND BLOOD-VESSELS.—Widespread arterial atheroma should certainly give to the surgeon who desires anæsthesia much fear as to the result. The great increase of the arterial pressure which takes place in nitrous-oxide narcosis may very well endanger the integrity of an atheromatous vessel. In 1890 a gentleman arose from a dentist's chair in Philadelphia after an inhalation of nitrous oxide, staggered, and fell in an apoplexy. Dr. F. A. Ashford[1] reports a case of a young woman who grew faint and dizzy shortly after waking from nitrous oxide, passed into a condition of disturbed consciousness, and found when she came fully to herself that her left arm was useless. It appears to me, therefore, that nitrous oxide should never be administered when there is marked degeneration of the vessels, and that the danger of its employment would be especially great if there should be an aneurism with feeble walls.

Ether certainly raises the blood-pressure, but the amount of increase is not nearly so great as when nitrous oxide is given. Moreover, in the majority of cases arterial degeneration is associated with either cardiac or renal disease, or very generally with both, so that the choice between the two anæsthetics is commonly to be dominated not by the atheroma itself, but by the coexisting disease. In atheroma with failing heart ether should certainly be preferred; in atheroma with renal disease and a normal heart chloroform would probably be the safer agent. Of course an apoplexy may occur at any time during an anæsthesia: the late Professor D. Hayes Agnew once lost a case during etherization; and in the *London Lancet*[2] is reported a case in which a chloroform inhalation was followed by aphasia, believed to be due to rupture of the cerebral vessels.

Valvular disease of the heart is sometimes alleged to be a positive con-

[1] *Amer. Journ. Med. Sci.*, vol. lvii., 1869. [2] Vol. i., 1870.

traindication to anæsthetic agents. When, however, the organic disease does not produce any absolute functional disarrangement of the heart, and when the heart-muscle is in a fair condition of health, anæsthesia may be induced, provided the circumstances of the case are such as to justify the surgeon taking a slightly increased risk. The key to the situation is not the valvular lesion, but the condition of the muscle; a loud murmur usually depends, to some extent at least, for its loudness upon the character of the valvular lesion, but it is also dependent, in part, for its loudness upon the force which drives the blood through the diseased orifice. A loud murmur is therefore, on the whole, not more strongly contraindicative of anæsthesia than is a feeble one; indeed, as the feeble murmur is more commonly associated with feeble walls, greater care must be exercised when such murmur exists than when a loud bruit everywhere forces itself upon the physician's attention. In all cases of heart disease whenever it is possible to avoid the use of an anæsthetic by the employment of cocaine or by other local device this should be done. No condition of the heart is, however, an absolute contraindication to the use of the anæsthetic; under certain circumstances anæsthesia may be produced when the heart is in advanced fatty degeneration. It must be remembered that the shock and nerve-strain which attend a major surgical operation without anæsthesia would endanger the arrest of a fatty heart even to a greater degree than would anæsthesia itself, so that the question is, after all, as to the imperativeness of the proposed operation.

In diseases of the heart ether is usually preferable to chloroform; indeed, when the heart is very feeble or the cardiac muscle is degenerated the action of chloroform upon the heart makes it a very dangerous remedy. In some cardiac cases there is a widespread pulmonic engorgement, with a tendency to exudation into the lung-vessels and smaller bronchial tubes. Under such circumstances the local irritant action of ether upon the mucous membranes is so deleterious that the surgeon is placed as it were between Scylla and Charybdis, and may in an individual case have great difficulty in deciding what is best. The A. C. E. mixture under these circumstances may be sometimes selected with propriety. Chloroform is especially dangerous when orthopnœa exists; it is doubtful whether in such a case its use is ever justifiable.

Respiratory Apparatus.—The existence of severe organic disease of the lungs seems to be a less serious bar to the use of anæsthetics than would be naturally expected. Of all the chronic pulmonic affections, probably emphysema, associated as it so frequently is with weakness of the right heart, causes the most solicitude to the anæsthetizer. The irritant local action of ether is an important element when the lining membrane of the tubes or air-vessels is seriously implicated; indeed, my own opinion is very positive that in some of the deaths which have occurred in persons with diseased kidneys from œdema of the lungs directly after etherization the cause of death has been the local irritant influence of the ether. It would appear, also, that widespread organic changes in the lung sometimes so interfere with the absorption of ether that it becomes exceedingly difficult to produce complete anæsthesia. The dictum of Hewitt, that in extreme emphysema in chronic bronchitis attended by expectoration and dyspnœa, and in advanced pulmonary

phthisis, chloroform or some mixture containing chloroform should be employed, is worthy of great respect.

In all cases of lung disease it is important to remember that the more chronic the disorder the less important is it as a contraindication to the use of an anæsthetic, and that anæsthetics are especially badly borne when there is acute or subacute pulmonary disease. Only under the most urgent circumstances should anæsthesia be attempted when in an acute pulmonary disease the symptoms are of sufficient intensity to produce even slight dyspnœa. In recent pleurisy or pleuro-pneumonia, with any embarrassment of the respiration or duskiness of the countenance, anæsthetization is attended with very grave risk.

In obstructive laryngeal disease, or when contraction of the trachea either from within or without, or other mechanical obstruction, produces dyspnœa, the greatest caution must be exercised in the use of the anæsthetic. Under these circumstances the chances of ether increasing the mechanical asphyxia by irritating the larynx or trachea are very great, so that chloroform is preferable to ether; or chloroform may be employed at first, and ether given when the reflexes have been abolished by the obtunding of the nerve-centres. When the laryngeal obstruction is of the nature of a spasm, and not of an organic change, the use of the anæsthetic is free from extraordinary danger; but it must be remembered that frequently in such cases there is more or less laryngeal irritation, so that chloroform is preferable to ether—a conclusion which is strengthened by the necessity which often exists for the prompt action of the anæsthetic.

In certain cases the mechanical obstruction may be a tumor in the mouth or other lesion above the respiratory tract proper, but if the respiration be interfered with, the general principles just enunciated hold good. Obstruction is a comparatively trivial matter, but, when it is complete, requires the surgeon by the use of the mouth-gag or other procedure to see that respiration through the mouth is unimpaired.

Operations.—The choice by the surgeon of an anæsthetic is often modified by the nature of the operation. In operations on the parts about the mouth it is often difficult to maintain anæsthesia on account of the mechanical interference on the part of the surgical operator. In such cases the rule should be for the patient first to be placed thoroughly under the influence of ether, and, unless the operation is to be a very lengthy one, to have been in this condition for several minutes before the surgeon begins. Usually, when the tissues and blood have been thus surcharged with ether, anæsthesia can be maintained by occasional whiffs of chloroform given as opportunity is afforded during the surgical procedure. Indeed, the first anæsthetic saturation is often sufficient to carry the patient through the more painful portion of the surgical work. In this, as in other cases, when chloroform is to be administered to an etherized patient it is essential to remember that often during etherization breathing is heavier and deeper than in the normal individual, so that it is entirely possible inadvertently to give an overdose of chloroform. The frequency of the entrance of blood into the larynx in these cases comes rather within the ken of the surgeon than of the anæsthetizer, but it seems worth while to copy the rules of Hewitt, that unless the convenience of the operator makes it

impossible, drainage from the mouth should be secured by the patient being placed in one of three positions:

1. Somewhat upon the side, with one cheek resting upon the pillow, and so that the face is turned slightly downward.

2. Sitting up, with the head and shoulders thrown well forward, the face looking toward the couch or bed.

3. Supine, with the head completely extended and in the mid-line.

As the diseases for which the operations of cerebral surgery are undertaken often in themselves contraindicate the use of anæsthetics, great importance attaches to the question of anæsthesia in these cases. Professor Victor Horsley has claimed that the hypodermic injection of morphine before the use of chloroform is in this class of operations exceedingly advantageous, not simply because it lessens the amount of the anæsthetic required, but also because it decreases the cerebral congestion and the consequent hemorrhage on section. This practice has had considerable following, but its correctness seems to be open to grave doubt. As long ago as 1863, Professor Nussbaum of Munich found that when hypodermic injections of morphine were given during chloroformization deep sleep continued for a considerable time after the withdrawal of the chloroform, and that the patient awoke without nausea or vomiting. In 1869 the researches of Claude Bernard were published, and led to the widespread trial of the conjoint use of morphine and chloroform.

A-priori reasoning would render it probable that anæsthesia would be more easily produced and would be more prolonged in the semi-narcotized patient than in the normal individual, and clinical experience has confirmed this. But in the prolongation of the anæsthesia would seem to lurk a danger. Certainly, it is but natural to suppose that an anæsthetic accident occurring in a person who is under the influence not only of a volatile and easily-dissipated poison, but also of a non-volatile and comparatively permanent poison, would be far more serious than if the failure of respiration or of circulation were the outcome purely of an agent which could rapidly be removed. Several surgeons have shown that this reasoning is not devoid of practical support, and a number of cases have been published in which very serious symptoms, or even death, have occurred during the mixed narcotism. In one case of Hewitt's the importance of the more persistent agent was shown by the fact that artificial respiration had to be kept up continually for four hours before any automatic breathing appeared, the fact indicating that, at least in that case, the morphine had more to do with the complete arrest of respiration than had the ether. Further, in many persons the use of opium is prone to be followed by excessive nausea and distress; in such an individual the disagreeable after-effects of the anæsthetic would certainly be aggravated.

Some surgeons consider that ether should not be used in abdominal surgery on account of the frequent respiratory movements, the cough, the retching, the vomiting, etc., which sometimes attend the employment of this anæsthetic, interfering with the delicate work of the surgeon. The presence of these disturbances, however, is usually an indication of improper anæsthesia. Rigidity of the abdominal muscles, retching, and general restlessness are to be overcome by the free use of the anæsthetic. The disturbances of respiration may depend upon

interference with the supply of air, or perchance may be the beginning asphyxial symptoms due to the excessive etherization. Violent and excessive vomiting after an abdominal operation is a serious thing, and certainly it is more apt to occur when ether has been used than when chloroform has been employed. It can, however, be largely prevented by proper method of administration.

Acute *intestinal obstruction*, with the general collapse which so often accompanies it at the time when the case comes into the surgeon's hands, requires great care on the part of the anæsthetizer, and some surgeons even go so far as to assert that complete anæsthesia at such times should not be produced.[1] The pain and terror, however, of abdominal section, the struggles of the patient, the general horrors of the situation, would seem to demand the use of the anæsthetic, even though the risk be grave. In such a case, before the anæsthetic be given, the stomach should always be thoroughly emptied, and no more of the vapor should be inhaled than is absolutely necessary; rapidity of action on the part of the surgeon becomes a matter of great moment, since the danger increases in almost geometrical ratio with prolongation of the anæsthesia. Ether is usually preferable to chloroform, though not rarely it is a very good practice to begin the anæsthetization with chloroform and afterward maintain it with ether.

KIDNEYS.—Writing in 1890, Dr. Lawrence Turnbull said that "it is of the greatest importance that attention should be given to the condition of the kidneys, and an examination made of the urine when an anæsthetic is to be administered. Deaths, unaccountable otherwise, are due to this cause. In diseases of the kidneys, the blood being loaded with urea, anæsthetics almost invariably produce convulsions, coma, and death." These words of Dr. Turnbull reflect a widespread professional opinion. If, then, disease of the kidneys be so strong a contraindication to the use of anæsthetics, it is necessary to examine very carefully as to the proper choice of the anæsthetic when, notwithstanding the existence of renal disease, anæsthesia must be superinduced. It is plain that two distinct dangers underlie the use of the anæsthetic in renal disease: one has to do with the influence of the drug upon the diseased kidneys; the other has to do with the relations between the secondary conditions of Bright's disease and the anæsthetic. Markedly atheromatous arteries contraindicate nitrous oxide; a degenerated heart-muscle contraindicates chloroform; and it may very well be that sometimes the choice of the surgeon should light upon the anæsthetic which threatens the kidneys most, because it is the least dangerous to those organs which have become secondarily diseased.

As throwing light upon sudden death during anæsthesia it is worthy of note that in Dr. Geo. B. Wood's experiments,[2] referred to below, several times in dogs who were suffering from nephritis artificially produced by the use of cantharides or present as the outcome of natural disease sudden fatal arrest of respiration occurred, suggesting that there may be in uræmia or uræmic conditions a special inability of the respiratory centres to resist the effect of narcotic poisons, and that amongst the secondary effects of Bright's disease should be put lack of resistive power in the respiratory centres.

[1] See *British Med. Journ.*, March, 1892. [2] *Univ. Med. Mag.*, vi., 1894, p. 802.

In attempting to decide as to the choice of an anæsthetic for an uræmic patient it is proper first to study the relations of the anæsthetic to the kidneys themselves. So far as my reading goes, Dr. Thos. A. Emmet of New York was the first to call attention to the possibility of the production of fatal suppression of urine in persons suffering from chronic Bright's disease by the use of ether. In his first experience complete suppression, and death in three days from uræmia, occurred in a patient suffering from chronic cystitis and probably renal degeneration. Subsequently to this Dr. Emmet is said to have had five such cases. Without attempting to go over the whole literature of the subject, attention may be called to the cases reported by Professor W. F. Norris to the American Ophthalmological Society in 1881, especially to the one in which death in convulsions followed ether anæsthesia in a child suffering from fatty kidneys, and in which after death the kidneys were found intensely congested. Various cases similar to these have been published in medical literature, and it does not suffice to answer, as has been done, that ether has been frequently employed in Bright's disease without bad results.

It ought to be possible positively to determine whether or not ether is capable of affecting the secreting structure of the normal kidney. In the *British Medical Journal*[1] Dr. Lawson Tait records a remarkable case in which, the ureters being exposed, it was found that the continuous administration of ether prevented the secretion of urine, and so long as the narcosis persisted there was no flow of urine. This observation is said to have been repeatedly confirmed by Tait himself,[2] and is of great importance as evidence that ether does affect the human kidney. It is evident that experiments upon animals should be made, in which, the ureters having been exposed and canulated, it should be determined whether these observations of Tait are exceptional or not. Albuminuria after ordinary anæsthesia is probably rare, but it certainly does occur at times. Patein[3] found it once in every three cases, but this is plainly much above the average. In elaborate studies made in the physiological laboratory of the University of Pennsylvania by my son, Dr. Geo. B. Wood,[4] it was found in dogs that during ether anæsthesia the kidneys become markedly congested, and almost invariably, if the anæsthesia had been protracted over fifteen minutes and the dog then killed, it was possible to demonstrate cloudy swelling of the nuclei and contents of the secreting cells. The cells of the convoluted tubules were those primarily affected, the tufts and corresponding tubules only showing change when the anæsthesia had been greatly prolonged. It is true that Fueter[5] failed to detect changes in the kidneys of etherized dogs, but this negative testimony can hardly stand against the positive evidence with specimens which were studied and accepted as conclusive by Dr. Guiteras, professor of pathology in the University of Pennsylvania.

These researches and studies may seem to the reader at first sight to demonstrate that chloroform is the safer anæsthetic when renal disease exists. The case is not, however, so clear, for it has undoubtedly been shown that chloroform itself has a very deleterious influence upon the

[1] Vol. ii., 1880. [2] *London Lancet*, Jan., 1883. [3] *Paris Thesis*, 1888.
[4] *Loc. cit.* [5] *Inaug. Diss.*, Leipzig, 1888.

kidney structure. Albuminuria has been noticed both in man and in animals after chloroform narcosis.[1] Dr. Eugene Fraenkel[2] has found that after death from protracted chloroform narcosis the secreting renal epithelium is in a condition of profound degeneration—a conclusion which he subsequently confirms, stating[3] that the alteration in the kidney epithelium is never wanting after death from prolonged chloroformization.

It would seem, therefore, that both ether and chloroform have a distinct deleterious influence upon the kidneys. I am myself inclined to believe that of the two agents ether is the more dangerous to the kidneys, especially on account of the great quantity which it is necessary to use.

The second division of the present subject concerns the relation of the anæsthetic to the secondary effects of kidney disease. The most dangerous of these secondary effects, so far as anæsthetics are concerned, and the one which almost invariably occurs if the patient live long enough, is degeneration of the heart-muscle. It is very evident that when this is present chloroform is a much more dangerous anæsthetic than is ether; indeed, under such circumstances the danger from chloroform grows extreme directly as the cardiac lesion deepens. The action of ether upon the secondary diseased tissues of the body in Bright's disease does not seem to me in any way especially deleterious. When, however, the condition of the body is such that there is tendency to the production of œdema of the lungs or to the filling up of the small tubules of the lungs with watery secretion, ether is highly dangerous. I believe myself that in a number of cases death has under such circumstances resulted from the sudden outpouring of serum provoked by the local irritant action of the ethereal vapor.

From what has been said it is plain that the selection of an anæsthetic to be used in a case of Bright's disease is a matter of grave responsibility, and must be based upon a consideration of all of the features of the individual case. If there be no secondary lesions, chloroform is probably safer than ether; if there be secondary lesions, especially secondary lesions affecting the heart, ether may well be safer than chloroform. In doubtful cases my own practice has been to commence the anæsthesia with ether, and when the stimulant effect of the ether upon the heart has become manifest to use chloroform, believing that in this way the least possible strain is put upon the heart and the kidneys.

AFTER-EFFECTS OF ANÆSTHESIA.

In discussing the choice of an anæsthetic I have refrained from any allusion to the after-effects of these agents, for the sufficient reason that our knowledge is at present so imperfect that it can scarcely be applied with safety. It is, however, necessary to show that the matter is of much more serious import than is generally supposed. The subject is, of course, beset with great difficulties: it may be almost impossible to decide how far any sequelæ which may follow an operation are due to the emotional strain which precedes and follows the work of the surgeon, to the ope-

[1] See H. C. Wood's *Therapeutics*, 9th ed., p. 149.
[2] *Virchow's Archiv*, Bd. 127, 1892.
[3] *Virchow's Archiv*, Bd. 129, 1892.

ration itself, to the anæsthetic, or to extraneous causes. Among the after-effects of anæsthesia various writers place insanity.

Mental Disturbance.—There can be no doubt but that confusional insanity often follows a surgical operation, but it is by no means certain that the anæsthetic has any causal connection with the cerebral disturbance. It is affirmed that in some cases symptoms of mental aberration have developed immediately after an anæsthesia. Dr. Geo. H. Savage[1] records a case in which violent delirium with insensibility of the conjunctiva, ending in three weeks in complete dementia, followed in a chronic drinker immediately upon nitrous-oxide inhalation. Such a case, however, obviously separates itself from one in which a true anæsthetic has been employed. It is entirely possible that during the venous stasis of the artificial asphyxia rupture of small vessels may occur or perhaps minute thrombi be formed in the cerebral cortex.

It is certainly exceptional for the symptoms of confusional insanity to follow immediately or even rapidly upon the anæsthesia. The disease is not a very rare one, and I have myself seen a large number of cases. In no one instance has any relation between the anæsthesia and the mental symptoms been traceable; always some days, and usually several weeks, have elapsed after the operation before the coming on of the mental symptoms. Under such circumstances the disturbance of mentality can hardly be attributed to the narcosis. Rather is it the outcome of a peculiar depression of the cerebral cortex produced probably by the coincident action of the shock of the operation itself, of the emotional strain, and of the various depressing factors inseparable from a surgical illness.

Disturbances of Renal Secretion.—The subject of the action of anæsthetics upon the kidney structure has already been, I think, sufficiently discussed in connection with the question as to the influence of disease upon the choice of an anæsthetic.

Many years ago a well-known Philadelphia surgeon attributed the diabetes which occurred, and finally proved fatal, in his own person to the inhalation of nitrous oxide, and in 1886 the French writer, Dr. Lafont,[2] affirmed that he had seen abortion with death of the fœtus occur at the moment of anæsthesia from nitrous oxide, and that he had noticed chlorosis, albuminuria, and especially true diabetes, follow the inhalation of the gas. He especially warns against the possible production of diabetes mellitus, reporting a case in which sugar appeared in the urine twice after use of the gas; and also stating that he had been enabled to produce glycosuria in the dog and also in his own person by the inhalation. The high blood-pressure which occurs during the nitrous-oxide narcosis is without doubt attended with venous stasis, and it does not seem, *a priori*, impossible to have as an after-effect of such narcosis various symptoms produced by change in the cerebral centres.

On the other hand, nitrous-oxide anæsthesia has been produced so many millions of times that, if it were really often the cause of serious after-effects, it seems hardly possible but that overwhelming evidence would be at this time forthcoming; and careful inquiry made by myself of persons whose sole business has been for years the administration of nitrous oxide for the extraction of teeth shows that in no instance have patients returned to them with complaints. Moreover, in experiments

[1] *Brit. Med. Journ.*, 1887.

[2] *La France méd.*, vol. i., 1886.

upon five dogs made by Drs. Geo. S. Woodward and Alfred Hand in the pharmacological laboratory of the University of Pennsylvania neither albuminuria nor glycosuria was produced by the repeated and prolonged inhalation of nitrous oxide. At present, therefore, it would seem that when the patient is a normal individual the surgeon should have no fear of any after-effects from nitrous oxide.

DISTURBANCES OF THE LIVER.—Frerichs states that jaundice sometimes follows the inhalation of chloroform and ether, but such cases must be of exceeding rarity. I have myself never met with them in literature, and Murchison states that after careful examination he has never been able to find a record of a case. On the other hand, Bernstein,[1] and also Leyden,[2] have found traces of bile-pigment in the human urine after chloroform narcosis; and Nothnagel[3] has recognized biliary coloring matters in the urine of rabbits after subcutaneous injection of chloroform or ether; but Kappeler[4] in twenty-five cases of chloroform narcosis was not able to obtain a trace of biliary coloring matter; further, chloroform mixed with blood outside of the body rapidly destroys the red corpuscles, liberating hæmoglobin, and it is possible that in rare cases of protracted chloroform narcosis some such action occurs within the body, yielding icteric products. On the whole, it does not seem probable that chloroform has any important influence upon the liver, save only as part of the widespread action upon the tissues next to be spoken of.

THE GENERAL NUTRITION.—As long ago as 1850, Caspar mentioned chronic poisoning by means of chloroform, and somewhat later Liman affirmed that after prolonged chloroformization patients sometimes pass into an abnormal condition which continues for days, even for weeks, and finally ends in death, the whole being the result of the influence of the chloroform. These views met with little acceptance, and, indeed, seemed commonly to have been overlooked or disregarded, until Dr. E. Ungar demonstrated by experiments upon the lower animals that prolonged chloroform narcosis has a profound influence upon the general nutrition.[5] He found that in the dog, when narcosis was kept up for many hours and repeated once or twice at short intervals, there was a widespread fatty degeneration, usually of a very high grade, in the heart-muscle and in the liver and kidneys, but more or less pronounced in the spleen, in the general epithelial tissues, in the voluntary muscles, and, in fact, in all of the higher tissues. That this change was not secondary to any alteration in the blood by the chloroform is believed by Ungar to be shown by the fact that no change could be noted in the red blood-corpuscles, nor were bile acids to be found in the urine, nor was there ever any hæmoglobinuria.

These researches have been confirmed in their general results in numerous experiments upon animals by Strassmann,[6] by Ostertag,[7] and by Kast and Mester.[8] Further, in a series of very careful studies upon four human subjects dying after prolonged chloroformization Dr. Eugene Fraenkel[9] has found a widespread necrotic degeneration, associated with

[1] *Moleschatt's Untersuchungen*, 1870.
[2] *Beitrage zur Pathologie des Icterus*, Berlin, 1866.
[3] *Berlin. klin. Wochensch.*, 1866.
[4] *Die Anæsthetica*, Stuttgart, 1880.
[5] *Vierteljahresb. f. Gerichtliche med.*, N. F., 46–47, 1887.
[6] *Virchow's Archiv*, Bd. 115.
[7] *Ibid.*, Bd. 118.
[8] *Zeitschr. klin. Med.*, xviii., 1891.
[9] *Virchow's Archiv*, Bd. 127 and 129.

a deposition of much pigment in many places and in all portions of the body, but especially affecting the heart-muscle and the epithelium of the kidney.

In further confirmation of the powerful influence of chloroform on nutrition there are the observations of Salkowski, that marked increase in the output of nitrogenous waste is caused by the administration of the drug to dogs; of Kast and Mester, that there is a marked increase in the elimination of chlorine and nitrogen produced by the anæsthetic; and of Petruschky, that after death from chloroform the intercellular juices become rapidly acid. Ostertag in his conclusions differs somewhat from Ungar in believing that the fatty degeneration is in part due to the destruction of the red blood-corpuscles by the chloroform. As, however, he also believes that the destruction of the protoplasm is in part effected by the direct influence of the chloroform, the difference between his views and those of Ungar is not vital. Moreover, whatever of scientific interest may attach to the method in which chloroform produces its ravages, to the surgeon the method is of little practical importance, the vital fact being that chloroform itself, directly or indirectly, destroys the living protoplasm in almost all portions of the human body. It seems to me, therefore, that it must be considered an established fact that a prolonged inhalation of chloroform directly affects the general nutrition of the vital organs, and is capable in this way of causing organic changes which may produce death very soon after the inhalation, or may take days or even weeks to work out the fatal result.

Certainly, enough has been made out in regard to the action of chloroform upon the nutrition to condemn the present total disregard by practical surgeons of this influence. When the anæsthesia is of short duration the influence of the chloroform upon nutrition is probably of little or no importance, but in those operations which require one or several hours for their performance the matter seems very serious. In such a case it is essential to select that anæsthetic which has the least influence upon nutrition. Unfortunately, though we know so much in regard to chloroform, we have no positive knowledge in regard to ether. Undoubtedly, it shares the power of chloroform of destroying the red blood-corpuscles and setting free the oxyhæmoglobin in freshly-drawn blood, but beyond this we have no evidence. *A-priori* reasoning, however, leads to the belief that ether probably disturbs nutrition much less than does chloroform. The researches of A. Zeller[1] indicate that chloroform is in part at least decomposed in the system. Chlorine is chemically very closely allied to iodine; the deleterious influences upon protoplasm of the iodine compounds set free by the decomposition of iodoform are well known; probably the chlorine compounds set free by the decomposition of chloroform act similarly. There is also much reason for the belief that bromide of ethyl is liable to be decomposed in the system and to yield bromine compounds capable of seriously affecting nutrition.

Ether is not eliminated to any appreciable extent by the kidneys: in the experiments of Dr. Geo. B. Wood it was found that whilst one drop of ether could be detected in two ounces of urine by the process used, no ether whatever could be found in numerous trials in the urine drawn at the time and at varying intervals after prolonged surgical etherization.

[1] *Zeitschr. f. physiolog. Chemie*, Bd. viii.

There is, of course, much escape of ether from the body through the lungs, but plainly it, like alcohol, is largely destroyed in the organism. In its destruction it must yield the same products as does alcohol, and, since no deleterious compound can be educed from it, it seems highly improbable that it should affect nutrition as does chloroform. On the other hand, it is probable that the long-continued use of alcohol will cause fatty degeneration, and the matter is so important that it should be at once put to the test of experiment.

In reviewing the whole subject it seems to me that, although our knowledge is imperfect, the *surgeon who desires to produce a prolonged narcosis should prefer ether to chloroform, unless there be in the peculiarities of the individual case positive reasons to the contrary.*

ADMINISTRATION.

Whenever it is possible the patient should be prepared for the use of an anæsthetic by an abstinence from food for at least four hours, and usually any food given inside of six hours should be very light and thoroughly digestible, so that the anæsthetizer can be sure of the emptiness of the stomach. Whenever circumstances render such preparation impossible, and the anæsthetic has to be given although the stomach is full, the greatest care should be exercised to prevent any of the contents of the stomach from entering the trachea. It should be remembered that vomiting may occur not only after the anæsthesia, but at any time during its course, in which case the patient should be placed with the head upon one side or partially downward to facilitate the possibility of discharge through the mouth. (See p. 660.)

It is a common belief, at least in some portions of America, that the administration of an ounce of whiskey or brandy before the use of the anæsthetic lessens the chances of severe nausea or vomiting. The correctness of this belief is not certain, although I deem the procedure a good one.

In cases in which there is any especial reason to fear the action of the anæsthetic upon the heart, a hypodermic injection of the tincture of digitalis may be administered from half an hour to an hour before the anæsthesia. Ten to fifteen minims thrown into the subcutaneous tissues with proper antiseptic precaution will rarely produce any local disturbance beyond some burning or smarting. In cases of very weak heart it would probably be wiser to begin to produce the influence of the digitalis twelve to twenty-four hours before the administration of ether. Even in ordinary cardiac cases the hypodermic use of strychnine before the inhalation may be of great service; and when there is a general tendency toward collapse or shock atropine or strychnine should always be administered to prevent, if possible, accident. The action of the various anæsthetics is so different that different methods of administration are required.

Etherization.—The instruments and methods which have been brought forward from time to time for the giving of ether by inhalation are legion, but all plans now in use may be arranged under two headings: first, open administration—methods in which free access of air is allowed; second, closed administration—methods in which the patient

breathes out of and into a bag with more or less imperfect supply of air.

It is evident that when a patient breathes in and out of a receptacle containing ether, in addition to etherization there is more or less complete asphyxiation, the degree of the asphyxia of course being dependent upon the size of the original reservoir of air and the amount of fresh air allowed to enter the reservoir during the inhalation.

Some years ago, at the clinic of the hospital of the University of Pennsylvania, etherization was produced by simply setting a large bottle freshly filled with ether in hot water, and connecting this with a face-mask which was so placed over the mouth and nose of the patient that the breathing was simply in and out of the bottle. The result of this simple apparatus was at first all that could be desired: anæsthesia was usually complete in two or three minutes, was well and thoroughly maintained, but the practice had not long been kept up when serious asphyxial accidents began to occur, and became so frequent and so severe as rapidly to lead to the abandonment of the method. There can be no doubt but that just in proportion as the patient is not allowed to breathe fresh air is the rapidity of the etherization hastened; but it seems to me apparent that in proportion as the rapidity of the coming on of anæsthesia is hastened, so is the danger of asphyxia increased.

I am not able to give positive statistics, but the number of deaths reported in the last eight years in England from ether is, I believe, much greater than those which have been reported as occurring in the United States, although ether is much more largely used in the latter than in the former country. The closed method of administration is very rarely employed in America, and it seems a natural conclusion that the closed method of administration is more dangerous than the open—a conclusion which is greatly strengthened by the fact that Dr. Hewitt, who practises the closed method, is continually cautioning his readers to see that the air-valves are opened, so that a free admission of air is allowed whenever previous disease adds more than the wonted danger to the use of ether. In recommending Ormsby's inhaler as superior to Clover's for maintaining etherization Professor Hewitt says: "I have often known cyanosis quickly to vanish and the breathing to become less hampered by effecting this change of inhalers during deep ether anæsthesia." I believe any closed inhaler hampers the breathing and increases the cyanosis of etherization. There ought not to be any cyanosis in etherization. My own experience with closed inhalers has not been large—indeed, solely with Clover's apparatus—but whenever I have seen closed ether apparatus used the evidences of asphyxia and early disturbances of respiration have certainly been much more frequent than I have been accustomed to witness with the open inhalation. The saving of ether effected by the closed method is of no importance whatever; the saving of time is very slight. In a series of observations which were made for me at the surgical clinic of the Jefferson Medical Hospital of Philadelphia the average time required for the production of complete unconsciousness by the open method was eight minutes; and in a similar series of observations made in the surgical clinic of the hospital of the University of Pennsylvania the average

time required for complete etherization by the Allis inhaler was seven and nine-tenths minutes. The results of these two series are so close that eight minutes must be considered as the average time required for full open etherization; with closed etherization this period can scarcely be shortened to less than four or five minutes.

Open Etherization.—Open etherization is often practised by simply folding a towel into the form of a cone, pinning the edges with safety-pins, and putting the ether inside. This is a rough and disagreeable plan—a plan which involves the greatest amount of suffering to the patient and the least amount of satisfaction to the surgeon. In many cases the towel is so used as mechanically to interfere with respiration. The inhaler invented by Dr. O. H. Allis is based upon the theory that the patient to be etherized should be supplied with an abundance of air saturated with the vapor of ether. It consists essentially of a series of foldings of muslin on a wire framework, arranged almost like the gills of a fish, so as to allow the air to pass freely through, but everywhere to come in contact with ether. It should be placed upon the face of the patient dry, and the ether gradually poured from a bottle whose cork has two small tubes so placed in it that when the bottle is tilted ether runs out of one tube and air enters through the other. Such a bottle is known in Philadelphia as the "polyclinic bottle." When properly used the Allis inhaler largely does away with the sense of suffocation, and the consequent struggles which have made etherization so repulsive alike to patient and surgeon.

Closed Etherization.—In England the Clover and Ormsby inhalers are very commonly used. Of these inhalers, Ormsby's appears to me to be simpler and the less dangerous, because of its being more open. The following general rules are copied from the recent book (1893) of Professor F. W. Hewitt, to which the reader is referred for further details. No one unaccustomed to the use of these inhalers should, in my opinion, attempt their employment without having carefully studied pages 145 to 150 of the work just alluded to.

Clover Inhaler.—1. Pour out any ether that may have been left from a previous administration.

2. In cold weather partially immerse the ether reservoir in warm water for a few minutes before use.

3. Pour in through the filling tube one and a half ounces of ether, replace the stopper or cork, and turn the indicator to "0."

4. Fit on a face-piece of appropriate size, and blow out through the apparatus, in order to expel all traces of ether vapor that might possibly be present in the shaft of the apparatus.

5. Gently but accurately adapt the face-piece to the face of the patient, and request him to breathe in and out quite freely.

6. When the patient is breathing freely attach the bag to the ether reservoir.

7. Allow the patient to breathe backward and forward for about half a minute before turning on any ether vapor.

8. Having allowed the patient to breathe his own expirations backward and forward for the time mentioned, very gradually rotate the ether reservoir, so that the "0" on its circumference moves almost imperceptibly but yet continuously away from the indicator.

9. Fresh air should not be given till there is a distinct indication for it.

10. When a breath of fresh air is given the strength of vapor should be increased, otherwise the patient may come out of the anæsthesia.

11. Should symptoms of excitement arise and struggling commence, the inhaler should be kept closely applied.

12. When the breathing has become regular and stertorous and the conjunctiva insensitive (these signs usually manifest themselves in about two and a half or three minutes) the inhaler should be removed for two or three breaths.

13. In ordinary cases it is unnecessary, in order to secure full anæsthesia, to rotate the ether reservoir beyond "3."

14. When once full surgical anæsthesia has become established the anæsthetist will be able to turn back the ether reservoir to "2," "1½," or even "1," and to admit air in sufficient quantities to avoid cyanosis.

15. Be careful to replenish the ether reservoir before the ether in it is exhausted.

Ormsby Inhaler.—1. Wring out the sponge in warm water, and, having squeezed it as dry as possible, place it in the cage.

2. Pour upon the sponge about half an ounce of ether.

3. Very gradually bring the inhaler toward the face of the patient, and if an air-slot be used see that it is open.

4. Encourage the patient to breathe as freely as possible, and gradually close the air-slot.

5. Be prepared for the patient attempting to push away the inhaler, rising from the bed, etc.

6. Should the sponge freeze, another one, wrung out as before, should be substituted and fresh ether added.

7. When more ether is needed about half an ounce at a time should be added to the sponge.

Except under the most peculiar circumstances the anæsthetic should always be administered by a skilled attendant rather than by the operating surgeon. This rule rests upon two foundations: In the first place, occasionally during the stage of anæsthetic excitement there is sexual stimulation which may go on to a complete orgasm and lead to after-complications if the operator and patient be of opposite sexes. In the second place, the person who gives the anæsthetic must pay the strictest attention during the whole period to the condition of the patient, as the life of the latter may depend upon the recognition of the early symptoms of accident. The celebrated Hyderabad Commission, in the most urgent and forcible terms, has drawn attention to the respiratory function as affording the chief seat of danger, and has asserted that failure of respiration always precedes, and is really the cause of, collapse of the circulation. There is no room for dispute as to the importance of a gradually produced asphyxia in the weakening of the heart, but cardiac depression and failure of circulation are just as important as is failure of the respiration, so that the anæsthetizer who neglects the pulse is most culpable. Both respiration and circulation must be relentlessly watched.

Failure of the circulation occurring at any time during anæsthesia is of most serious import, but the meaning of respiratory failure depends upon when it occurs. Especially is this true if ether be employed.

Early in etherization the irritating influence of the vapor upon the mucous membrane and the fauces of the upper respiratory tract frequently produces reflex disturbances or even arrest of the respiratory movements. Such an occurrence should, however, be the signal for giving the anæsthetic more freely, since the respiratory disturbance is not accompanied with any danger, and is at once suspended when sufficient of the anæsthetic has been taken to obtund the nerve-centres. On the other hand, any irregularities of respiration occurring after anæsthesia has been thoroughly induced imperatively demand the immediate withdrawal of the anæsthetic. In 1874, Dr. Baudin called attention to the pupil as a guide in chloroformization, stating that it is at first uniformly dilated, but afterward is uniformly and immovably contracted, and that the period of contraction is the period for operation. Since the publication of Baudin's memoir the matter has been much discussed both by physiologists and clinicians. As a general rule, during deep chloroform anæsthesia there is decided but not minute contraction of the pupil, and if during the anæsthesia the pupil returns to norm, more chloroform is required, but if it suddenly dilate, danger is imminent. It has been shown, however, by the experiments of Holmgren, Kratschmer, and others that this general rule is often departed from—that in the lower animals the pupils vary greatly during chloroformization; and there can be no doubt that this is also true in regard to man. Sometimes the pupil dilates early in the chloroformization, and remains dilated through the complete anæsthesia; again, nor rarely, especially when the operation occurs in the region of the neck, the pupil alternately dilates and contracts during a chloroformization.

During etherization the common rule is for the pupils to be of moderate size or even slightly dilated, whilst in very deep ether anæsthesia there is often, perhaps commonly, pronounced dilatation. On the other hand, in a considerable proportion of cases the pupils contract during etherization, whilst in other cases the size of the pupil varies very much, and often inadvertently, during one etherization. It is evident that the pupils cannot be relied upon as a guide during the administration of an anæsthetic, though some inference may be derived from their study.

Much more important to the anæsthetizer are the color and expression of the face. The face should be carefully watched; any cyanotic appearance denotes approaching asphyxia, whilst an excessive pallor is indicative of failing circulation. Severe anæsthetic accidents are often, if not usually, immediately preceded by a sudden change sweeping over the expression of the face like the alteration of the summer landscape by a flying cloud. This danger-signal is so important, so frequent, and so imperative that the anæsthetizer should always carefully watch the countenance of the patient.

The importance of a careful watch over the pulse is so obvious as not to need any detailed discussion here, and I only call attention to the convenience of the temporal artery for the purposes of the anæsthetizer.

Any danger-signal occurring during the administration of an anæsthetic should lead to the immediate withdrawal of the inhaler and the attempt at resuscitation of the patient. The measures employed for the latter purpose of course vary according to the direction from which the danger comes. Usually the first procedure is to see that there is no

obstruction to the respiratory passages by the throwing back of the paralyzed parts upon the larynx. Various methods have been advocated. Formerly all that was considered necessary was simply to draw forward the tongue, but Dr. Benjamin Howard showed that this does not necessarily accomplish the purpose, and proposed the extension of the head and neck. In an elaborate series of experiments, however, made in the laboratory of the University of Pennsylvania, Drs. Hobart A. Hare and Edward Martin proved that the method of Howard is often inefficient, and that the best results are to be obtained by carrying out the following rule: "Place the index finger of each hand upon the corresponding cornua of the hyoid bone, whilst the middle fingers rest upon the angle of the jaw, and then press forward and upward, the same force serving to extend the head upon the neck; if this fails to open the glottis, by means of a tenaculum thrust far back into the base of the tongue draw it forward."

Whilst the manipulation spoken of is going on an assistant should strip the chest of the patient, and by slapping it with a cold wet towel or by pouring a little ether over it, so as to get the effect of cold, should endeavor to stimulate respiration. If there be failure of the pulse, no time is to be lost; inversion of the body is to be practised immediately. This method of treating anæsthetic cardiac failure has been commonly claimed, especially in Europe, as having originated with the Parisian surgeon, Nélaton, but the profession is really indebted for it to an American, Dr. E. L. Holmes of Chicago, who as long ago as 1868, speaking of anæsthetic accidents, said: "Whenever there is any failure of the heart's action, as is nearly always the case, the body should be laid at an angle of forty degrees, with the head downward, so as to favor the passage of arterialized blood to the brain."

Inversion of the body does not, however, act as a resuscitant in the manner which was believed by Dr. Holmes and universally accepted by the profession. The series of experiments which I made for the address delivered before the Berlin Congress of 1890 demonstrated that in the body of the animal whose circulation has been paralyzed by chloroform the whole arterial and venous system acts in a measure like a single tube filled with fluid. Thus, if the feet of the dog were raised vertically above the head whilst the latter remained upon the table, an immediate rise of pressure always occurred in the carotid artery, even if the heart had practically ceased beating, provided that the head of the animal was kept upon a level with the table—that is, upon a level with the manometrical tube. If, however, the head of the animal was depressed below the level of the table for a distance equal to, or greater than, the length of the body of the animal, a decrease of the arterial pressure occurred at once, although the animal was in a vertical position. The phenomena observed were precisely such as would have been produced if the canula had been inserted into a tube filled with fluid, instead of into the carotid artery, and the elevation and depression of this tube had registered itself on the recording drum in obedience to the ordinary laws of hydrostatics. The phenomena were entirely independent of any beat of the heart, and could usually be produced when the animal was dead, provided the death had not occurred too long previously. Sometimes, even a very few minutes after the cessation of the heart-beat, it was impossible to

bring about the changes of pressure, probably because coagulation of the blood had occurred to an extent sufficient to interfere with the liquid properties of the fluid. In no case was any effect upon the respiration caused by change in the position of the animal. In a number of cases, however, when the feet were elevated the heart, which had entirely ceased beating, recommenced its work, and I have several times seen a pulse entirely disappear when the animal was taken from the vertical to the horizontal position. On the other hand, very frequently it was impossible to affect the cardiac action by changing the position of the animal. Nevertheless, the restoration of cardiac movements occurred too frequently to be a mere outcome of chance, though I several times noted that the heart was more affected by alternately elevating and depressing the feet of the animal than by keeping it in a steadily elevated or horizontal position. The action of inversion in the anæsthetic accident is therefore not upon the respiratory centre, but upon the heart. When the circulation has practically ceased in anæsthesia, inverting the body must cause the blood which has collected in the extremely relaxed vessels of the abdomen to flow into the right side of the heart and distend it; and this distention, this increase of intra-cardiac pressure, may at a critical moment have an influence upon the failing organ sufficient to recall it into functional activity.

The question of the use of drugs in these accidents is, of course, an extremely important one. The more important remedies which previous to 1890 were used by clinicians for the averting of threatened death were ether, alcohol, ammonia, amyl nitrite, digitalis, atropine, and caffeine. Although, at least in America, hypodermic injections of ether have been frequently employed, even in ether accidents, such use is so absolutely absurd that it does not seem to me to require any experimental evidence of its futility. Ether in the blood acts as ether, whether it finds entrance through the lungs, through the rectum, or through the cellular tissue; and the man who would inject ether hypodermically into a patient who is dying from ether should, to be logical, also saturate a sponge with the ether and crowd it upon the nose and mouth of his unfortunate victim.

Of all the drugs, that which was primarily most relied upon by the clinicians as a cardiac stimulant in anæsthesia was alcohol. The chemical and physiological relations of alcohol to ether and chloroform are, however, so close that many years ago I became very doubtful of the value of this drug as a stimulant to a heart depressed by anæsthesia. These doubts continually grew stronger from what I saw and read as to the effects of the administration of alcohol during anæsthesia, and were finally changed into conviction by the experiments of R. Dubois,[1] who found that in the animal to which alcohol has been freely given much less chloroform is required than in the normal animal to anæsthetize or to kill; or, in other words, that alcohol intensifies the influence of chloroform and lessens the fatal dose.

In my own experiments, made for the address already spoken of, from 5 to 20 c.c. of an 80 per cent. alcohol, well diluted with water, were injected into animals in which the heart was failing during advanced chloroform anæsthesia. In no case was I able, whether the amount was

[1] *Progrès médical*, 1883.

large or small, to detect the slightest increase in the pulse-wave or in the arterial pressure produced by the alcohol. Whenever the amount of alcohol was sufficiently large to produce any effect, there was always an increase of rapidity in the fall of arterial pressure and also a lessening in the size of the pulse-waves. I have myself no doubt that in not a few cases deaths which have been attributed to ether and other anæsthetics have been in fact due to the alcohol which has been given to the patient; and it seems to me an *unalterable rule of practice that no alcohol should ever be given to the patient suffering from anæsthetic cardiac failure.* If in the course of the anæsthesia cardiac failure results from hemorrhage or other surgical cause, alcohol may seem to some surgeons to be indicated, but under these circumstances any good effect which would be obtained by alcohol would be more rapidly reached by the further administration of ether.

The effect of ammonia upon the failing heart of chloroform anæsthesia has been in my experiments uncertain—sometimes distinct, sometimes very fugacious, sometimes imperceptible. Twenty cubic centimetres of a 10 per cent. solution of aqua ammoniæ fortior (U. S. Pharmacopœia) injected into a vein in the anæsthetized dog did sometimes produce an immediate rise in the arterial pressure, and even fugaciously register itself in the respiratory rate, but perhaps more frequently it failed in its influence.

The influence of injections of digitalis has been, in a number of experiments, very pronounced in causing during anæsthesia in the dog a persistent gradual rise of the arterial pressure with an increase in the size of the individual pulse-beats. In several instances death was apparently averted by its injection, and I saw in one or two experiments, in which large amounts of the digitalis had been employed, sudden systolic cardiac arrest, indicating that digitalis, if in sufficient amount, is able to assert itself victoriously in opposition to chloroform. Moreover, when I have given chloroform to dogs whose hearts were already under the influence of digitalis there has seemed to be a peculiar steadying or sustaining power combating the circulatory depression naturally produced by the anæsthetic, and I believe that *in all cases of weak heart in man a full dose of digitalis given hypodermically before the administration of chloroform* would greatly lessen the danger of cardiac collapse.

With amyl nitrite, for which much has been claimed as a cardiac stimulant, I was never, in my experiments, able to obtain any rise of the arterial pressure, and very rarely any alteration in the size of the pulse-wave; occasionally the pulse-wave did appear to be a little fuller. My own belief is that the amyl nitrite is a doubtful remedy which must be used with the greatest caution in anæsthetic syncope; certainly the least overdose most seriously adds to the depression of the heart.

Of all the experimental results which I reached, those with strychnine were to me the most surprising. I found that the injection of strychnine into the jugular vein of a dog whose circulation and respiration were failing from an overdose of chloroform was usually followed by a gradual rise of the arterial pressure, and always by an immediate and extraordinary increase of the rate and depth of the respiration. Thus I have seen a respiration which had practically ceased for ten seconds, under the influence of the injection of strychnine become at once very

large and full and reach the rate of 130 a minute. In order to get any effect from the alkaloid, however, it is essential to give it in large doses; to a robust adult with serious anæsthetic heart or respiratory failure $\frac{1}{18}$ of a grain may be given at once hypodermically.

I have never performed any experiments to determine the effects of cocaine in anæsthesia, but I have proven it to be one of the most powerful of the respiratory stimulants, and that it is also able to act as an adjuvant to strychnine, so that in the chloralized dog, when the respiration has been raised as far as could be done with strychnine without incurring too much risk of poisoning, cocaine was able still further to improve it. I believe, therefore, that hypodermic injections of strychnine and cocaine would act more effectually in the accidents of anæsthesia than would either alkaloid by itself.

The most remarkable results which I have reached in bringing about recovery of animals to all ordinary intents and purposes dead were obtained through the use of artificial respiration. Thus I have seen an animal in which no respiratory movements whatever had taken place for two minutes, and in which during that time no movements of blood had occurred in the carotid artery, and in which, therefore, the heart had practically ceased to beat, rapidly and permanently restored by artificial respiration. I have no doubt that in a large proportion of the deaths which have occurred in man from anæsthesia the fatal result might have been avoided by the use of an active artificial respiration. The difficulty with artificial respiration, as it has been hitherto practised upon man after the Sylvester or other methods, is its inefficiency; whereas the artificial respiration of the physiological laboratory is much more efficient than natural breathing in causing circulation of air through the lungs, and therefore in removing excess of the anæsthetic from the residual air in the lungs and from the blood. The use of what may be called "forced" artificial respiration by the physiologist so naturally suggested a similar practice in man that the celebrated John Hunter invented for the purpose an apparatus which consisted of a bellows so constructed that when it was extended one compartment drew in air from the lungs, whilst the other drew air from the atmosphere, and when it was closed the process was reversed, the fresh air being thrown into the lungs, the foul air into the atmosphere.

There is, however, no need of drawing the air out of the fully-filled lungs; the chest-walls even after death, much more during life, have sufficient elasticity to force the air out of the lungs, and all ordinary laboratory apparatus for artificial respiration is based upon this fact. For forced artificial respiration upon man an ordinary bellows is all that is required for the motive power. In 1887, Dr. George E. Fell of Buffalo introduced the use of forced respiration to the profession as a means of treating morphine-poisoning, and devised an apparatus which consists of a pair of foot-bellows by which air is forced into a receiving chamber, which in turn is connected with an apparatus for warming the air, and a valve which can be opened and shut by a movement of the finger. This valve in turn leads to the tracheal tube. When the valve is opened the air rushes through the chamber into the lungs and expands them; the finger is lifted, the valve shuts, the lungs contract; and so the respiration goes on. I have no doubt that this apparatus is very

efficient in practice, but it seems to me to be open to the serious objection of being unnecessarily complex and costly. A much cheaper, simpler, and probably equally efficient apparatus may consist simply of a pair of bellows of proper size, a few feet of india-rubber-tubing, a face-mask, and two sizes of intubation-tubes; there should also be set in the rubber tubing a metal tube, similar to the tracheal canula of the physiological laboratory, so that it is in the power of the operator to allow for the escape of any excess of air thrown by the bellows. I suppose this whole apparatus could be prepared at the expense of less than five dollars, and it seems hardly necessary to point out its probable value, not only in narcotic poisonings, but in all accidents or diseases in which life is threatened by a temporary paralysis of the respiratory centres.

THE TECHNIQUE OF ANTISEPTIC AND ASEPTIC SURGERY.

By ARPAD G. GERSTER, M. D.

I. Infection, its Agents and Carriers.

Modern surgery, as understood and practised to-day, has been made possible by two things. One was the discovery of anæsthesia; the other, the firm establishment of the Listerian principle of surgical cleanliness. The changes brought about by the general acceptance of the Listerian principle are rarely realized by that younger generation of surgeons whose medical education was finished after 1885. The terrors of the surgical practice of those former days—terrors which surgeon and patient faced meekly and in resigned despair—such as unavoidable suppuration, pyæmia, septicæmia, erysipelas, tetanus, and, worst of all, hospital gangrene, are so rare now that some of them, notably hospital gangrene, may safely be declared to be extinct. All of them are looked upon now as exceptional and always due to ascertainable and avoidable conditions. Hence, even suppuration not being considered an unavoidable but rather an unusual complication, the possibility of its occurrence is allotted a diminishing share in the determination of the advisability of all operations.

Adequately to point out the enormous practical gain due to modern methods as compared with pre-Listerian results, it may suffice to state that, according to Lindpaintner,[1] "80 per cent. of all wounds"—treated in Nussbaum's clinic in Munich—"were attacked by hospital gangrene. Erysipelas was the order of the day to such an extent that its occurrence could almost have been looked upon as the normal course; not to suture any scalp-wound was a firm principle; healing by primary union did not exist, and suturing of a wound would have simply led to retention and the further encouragement of erysipelas. Within one year 11 out of 17 patients subjected to amputation died of pyæmia; to observe the course of a compound fracture was a great rarity in our clinic, as it was customary to perform amputation immediately, otherwise purulent infection, hospital gangrene, or septicæmia led to a fatal termination within a few days." In Volkmann's clinic at Halle the usual rate of mortality in compound fracture was 40 per cent.

To illustrate by American examples we may mention that Ashhurst[2] in 1881 gives a rate of mortality of 28 per cent. after 100 major amputations performed by himself, judging this to be below the general average, which was about 33 per cent.

[1] *Deutsche Zeitschrift für Chirurgie*, 1877.
[2] *Encyclopedia of Surgery*, vol. i. p. 617.

What a change has taken place since then is attested by the remarkable improvement in the death-rate after all forms of operative work. To give an instance, it may be stated that of 318 major amputations done by Volkmann under antiseptic precautions, 28 cases ended fatally; that is, his rate of mortality was about 9 per cent.[1] Still another and more forcible illustration of the influence of antiseptic principles is the report of Dennis comprising 1000 cases of compound fracture treated by him in four large metropolitan hospitals, covering a period of several years, with a death-rate from septico-pyæmia of $\frac{1}{7}$ of 1 per cent. This is in marked contrast to the published report in pre-antiseptic days of the Obuchow Hospital of St. Petersburg, where the death-rate reached as high as 68 per cent. in 106 cases of compound fractures; or of the Pennsylvania Hospital from 1831 to 1851, where the death-rate was 44 per cent. in 116 cases; or of the New York Hospital during the same period, where the mortality was 48 per cent. in 126 cases.[2]

A corresponding improvement is observable in all other branches of surgery. The large cavities of the human body are fearlessly invaded now, the cranial contents, the pleura, peritoneum, or large joints form no more a *noli me tangere*, and what used to be called the surgeon's "luck" or "misfortune" is now considered to be the direct consequence of a sound or of an improper technique of cleanliness.

In another direction great progress for the better has been secured, materially affecting the welfare of patients and hospital economics, inasmuch as the average duration of time needed for curing most surgical complaints requiring operation has been materially reduced, To give a typical illustration, it may suffice to say that where in former days three to six months were consumed in healing the wound after ablation of the mamma, two to four weeks are at present amply sufficient for the purpose.

It is a matter of curious interest to see the laborious compilation of statistical tables contained in many of the older works on surgery, in which the influence of the external temperature, the seasons, barometric pressure, sex, nationality, or race exerted upon the success of operations is seriously considered. We know to-day that the healing of a wound is entirely uninfluenced by these as well as by other factors formerly considered important, such as, for instance, constitutional taint or individual predisposition. This change for the better is solely due to our knowledge that, like fermentation and putrefaction, the infection of wounds is directly due to the importation and proliferation of minute organisms. Protect the wound from these organisms and it will heal kindly in a tuberculous, syphilitic, or cancerous subject in man and woman, in the young and old.

a. Atmospheric and Contact Infection.—The belief that the air may be, and often is, the medium of the transportation of morbid agents is as old as human tradition. The knowledge that the course of subcutaneous injuries is widely different from that of open wounds was clearly expressed by John Hunter, since whose time it has assumed the character of a surgical tenet. Yet the nature of the precise agent contained in the atmospheric air, and notoriously injurious to wounded tissues, remained a mystery. Malgaigne's experiment of pumping the

[1] Oberst: *Die Amputationen, etc.*, Halle, 1882.
[2] *Philad. Medical News*, April 19, 1890.

subcutaneous tissue of animals full of atmospheric air, thus rendering them emphysematous, then fracturing bones, dividing subcutaneously tendons, etc., without producing suppuration, only served to thicken the mystery.

It is Lister's immortal merit to have directed surgical endeavor into the right channels in utilizing the hints afforded by the labors of Pasteur and others. He showed that the decomposition of dead organic substances is due not to the gaseous, but to accidental and corpuscular, elements floating in the air. As a direct outcome of the theory that disturbances in the healing of a wound were produced by a sort of fermentation analogous with the decomposition observed in dead organic matter, Lister endeavored to destroy the noxious contents of the air by the use of his carbolic spray, and sought, further, to prevent the ingress of these organisms into the wounds by the employment of various occlusive measures, the final form of which, the typical Lister dressing, revolutionized surgery. Though the theory lacked scientific confirmation, the enormous improvement of the results of surgical operations done under Lister's precautions, as compared with former ones, was very apparent to candid observers.

The fierce and unphilosophical opposition of Lister's countrymen did not prevent Volkmann from studying and benefiting by the new light issuing from Scotland, and to his unreserved and generous approbation is due the rapid acceptance of Lister's principle throughout Germany, the continent of Europe, and America. To England belongs the doubtful distinction of harboring the last remnants of a truculent negation of what the grateful world has learned to value as a great benefaction to suffering humanity.

As before mentioned, Lister's theory lacked scientific proof long after its great utility had been abundantly proven in surgical practice. The actual scientific demonstration of the micro-organisms causing wound-infection, their separation and classification by secondary culture, in short, their natural history, are the outcome of the methods of research originated by Robert Koch, who furnished the long-lacking scientific proof of the correctness of the Listerian theory.

Bacteriology has shown that the air contains various micro-organisms in varying proportions and quantities, the variations being very great under different circumstances. While bacteria and cocci prevail in the air of inhabited dwellings, the spores of mould and the fungi of alcoholic fermentation form the majority of the micro-organisms contained in the open air.

We know that the air of cities contains more germs than that of the country; that in dry weather there are more germs floating in the air than in rainy weather; and that the air carries more germs when there is wind than when it is calm. The air in mid-ocean, on top of the highest mountains, and in the middle of large tracts of uninhabited damp forests is practically germ-free. A sea-breeze carries fewer germs than a land-breeze.[1]

These facts point irresistibly to the assumption, now abundantly

[1] Condorelli-Mangeri: "Variazioni numeriche dei micro-organismi nell' aria, etc.," *Atti dell' Academia, etc.*, Catania, 1888, Ser. iii. T. xx.; Uffelmann: "Luftuntersuchungen," *Arch. für Hygiene*, Bd. viii., 1888, p. 262.

proven, that the nidus of all minute organisms is not the air—that they are not bred in the air, as formerly believed, but that their breeding-places are to be looked for in organic substances, mainly on the surface of the earth, whence they are occasionally and temporarily displaced to float in the air. As soon as the disturbing agents subside the floating germs will settle back on the surface.

Organic germs will best float in air when they assume the form of dry powder or of dust; and Naegeli has demonstrated that they will never enter the air from fluid media by the instrumentality of ordinary agents, such as common winds or drafts of air. Hence the belief that sewer-gases may cause infectious diseases is erroneous, as the stinking air of a damp sewer contains, as a rule, fewer germs than the best ventilated or unventilated dwelling or the open street. To become dangerous the contents of the sewer or water-closet must be first dried, then pulverized, and finally wafted in air.[1] It may be added that micro-organisms may be carried from liquid media into, and remain suspended in, the atmosphere by inordinately strong winds, such as prevail during storms. This is explained by the tendency of strong winds to dash water against shores, to make the waves break, and thus to produce spray, which is readily transported by high winds.[2]

In further confirmation of the fact that dryness and agitation of the air favor the increase of the number of micro-organisms contained in it, may be mentioned the facts that Condorelli-Mangeri found in the air of Catania a decided increase of germs at times when a fair or other popular gathering was held. The relative number of germs will rapidly increase in the air of workshops after work has commenced, and the same thing is observed as to the air of barracks, hospital wards, and dwellings shortly after their being swept and dusted. According to Hesse, in the air of school-rooms, originally containing 3000 germs per cubic metre, their number will increase to 20,000 during school-hours, and to 40,000 when the children leave school.

It is of considerable interest to note that the breath of healthy and diseased animals or human beings, be it however foul, has never been found to contain micro-organisms. The moist surfaces of the bronchi and lungs act as a filter by which germs carried into the respiratory tract are retained, the expired air being almost entirely free from germs.[3]

Thus we find that all microbes found suspended in air are derived from the exposed surfaces of organic material. In examining the relative proportion of living germs contained in sputa, pus, street-dirt, slops, and the water of open sewers and canals we encounter truly appalling quantities, and far outnumbering anything ever found in the foulest atmosphere. According to the researches made by the Berlin Hygienic Institute, each cubic centimetre of the water of the river Spree contains from 3200 to 154,000 germs, the average being 37,525.[4] There are in each drop of pus millions of microbes, and similar proportions prevail as to every kind of decomposing organic material. Compared with this,

[1] Petri: "Eine neue Methode, Bacterien-Polysporen, etc.," *Zeitschrift für Hygiene*, 1888.
[2] Fontin: *Wratsch*, 1888, Nos. 49 and 50.
[3] Strauss: "Sur l'absence des microbes dans l'air expiré," *Annales de l'Inst. Pasteur*, 1888, p. 304.
[4] Schimmelbusch: *Aseptische Wundbehandlung*, p. 13.

the 40,000 germs found in a cubic metre of the vitiated air of a lecture-room are truly insignificant.

With these facts in view, the statement may readily be accepted that *contact* of a wound with any of these substances will involve a much greater chance of infection than exposure to atmospheric air. And long before actual proof of these relations existed, the results of actual practice had demonstrated that Lister's fears of aërial infection were exaggerated. Hence the early abandonment of the carbolic spray and the later one of irrigation. The only precaution worth taking against the possibility of atmospheric contamination of a wound is the avoidance of acts tending to *stir up dust*. Sweeping, dusting, and ventilating of localities to be shortly used for operative work is improper. These procedures should be gone through with far enough ahead of the time of operation to permit the laying of the particles of dust before the operation begins. Should time be lacking to fulfil this condition, it will be best not to disturb any hanging or piece of furniture, not to open doors and windows simultaneously; in short, to avoid everything tending to stir up dust.

b. Infective Agents.—As the subject of surgical bacteriology has received adequate treatment in the preceding articles of this work, it will be sufficient to point out the practical outcome of the labors of the bacteriologist as far as they concern the surgeon. Though it is known that certain substances, organic and inorganic, injected into living animal tissues, are apt to cause a process similar to microbial suppuration, it is just as well known that this manner of causation is very rare, and in no wise comparable as to frequency and general importance with the forms of progressive suppuration directly dependent upon the action of the various pyogenic micro-organisms. The overwhelming majority of suppurations, and other disturbances of a similar nature to which the human tissues are subject, certainly depend upon the direct influence of pathogenic germs imported from without. Their proliferation and the local and general effect of their products constitute what are termed "infection" and "disease;" that is, a progressive development of symptoms well defined and typical. This *progressive* character of the symptoms accompanying the lodgement and proliferation of pathogenic organisms in the living tissues is what distinguishes an infectious process from other processes similar to, but essentially different from, the former, and produced by chemical, mechanical, or caloric agencies.

With a full understanding of the overwhelming importance of the microbial factor in producing certain morbid states, it would yet be one-sided to attribute the production of these morbid conditions to the presence of microbes alone, and to nothing else. Although we admit that ordinarily there cannot be suppuration without microbes, we know, on the other hand, that the presence of microbes in itself will often fail to cause suppuration unless the state of the tissues themselves or the general state of health favors their germination. In what this predisposition of certain tissues of a body consists we do not know; nor can we positively define why the same individual will show different degrees of resistance to the same form of infection at different times. So much, however, is fairly certain, that to account for the various forms of microbial infection we must assume two nearly equally important factors: First, the

lodgement of pathogenic organisms within the living tissues; and, secondly, a condition of these tissues favorable to the development and multiplication of microbial growth. To illustrate this relation of things it may suffice to mention the marked predisposition to suppurative processes observed in diabetes mellitus.

II. Disinfection and Sterilization.

Foremost among the means for disinfection stand the homely but thoroughly efficient and sound methods of *mechanical purification*, as, for instance, maceration, scrubbing, washing, scraping, shaving, with or without the aid of emollients, among which the principal one is soap. Being aware of the fact that the sparse number of infectious germs contained in the air is far outnumbered by the millions of microbes incorporated with the various forms of gross filth and dirt adherent to almost every surface exposed to contact with the outer world, our principal endeavor at disinfection must be directed, in the first place, toward the removal of these gross lumps of filth. How much can be accomplished in surgery by means of these simple methods was first demonstrated by the brilliant results of men like Lawson Tait, whose reliance was placed almost exclusively upon ordinary measures of personal and domestic cleanliness. The *mechanical removal of the great bulk of microbial dirt* from the objects to be brought in contact with a wound *is the most important preparatory act of all forms of disinfection.*

Methods of chemical disinfection have undergone manifold changes since the days of the universal reign of carbolic acid. Formerly, some deodorizing agents were considered good disinfectants, and the valuation of the merits of the various disinfectants was extremely uncritical. We owe the more correct appreciation of the value of these substances to the labors of Koch, who by pure culture taught us to isolate the several species of pathogenetic germs, and showed us how to recognize their different vegetative forms.

Some of these microbes are productive of spores; others are sporeless. In general, it may be said that the spores of micro-organisms offer a much greater resistance to disinfecting agents than the mother-plant, and, furthermore, it was learned that the different species of microbes also differ from each other materially in this respect.

In estimating the bactericidal value of a chemical disinfectant a number of precautions[1] have to be observed to eliminate errors, and discrimination must be used in applying the results thus gained to the actual conditions met with by the surgeon in his practice.

Another factor materially influencing the development of microbes is the presence or absence of certain cardinal conditions necessary for their proliferation. A suitable pabulum, a certain quantity of moisture, and a certain temperature are indispensable. *Withdraw one or more of these conditions, and the microbes will either perish or their growth will be retarded.*

For ascertaining the relative value of a number of the common disinfectants, as to their power of retarding bacterial growth, Koch selected the spores of the anthrax bacillus, one of the most resistant forms of

[1] Geppert: "Zur Lehre von den Antisepticis," *Berl. klin. Wochenschrift*, 1889, No. 36.

pathogenetic bacteria. The results of his investigation are contained in the following table:

In the proportion of—	Growth markedly checked.	Entire cessation of growth.
Bichloride of mercury	1 : 1,600,000	1 : 300,000
Oil of mustard	1 : 333,000	1 : 33,000
Arseniate of potash	1 : 100,000	1 : 10,000
Thymol	1 : 80,000	
Oil of turpentine	1 : 75,000	
Osmic acid	1 : 6,000	
Oil of cloves	1 : 5,000	
Potash soap	1 : 5,000	
Iodine	1 : 5,000	1 : 1,000
Salicylic acid	1 : 3,300	1 : 1,500
Camphor	1 : 2,500	1 : 1,250
Eucalyptol	1 : 2,500	1 : 1,000
Borax	1 : 2,000	1 : 700
Benzoic acid	1 : 2,000	
Bromine	1 : 1,500	
Chlorine	1 : 1,500	
Permangan. potash	1 : 1,400	
Boracic acid	1 : 1,250	1 : 800
Carbolic acid	1 : 1,250	1 : 850
Quinine	1 : 830	1 : 625
Chlorate of potash	1 : 250	
Alcohol	1 : 100	1 : 12.5
Cooking salt	1 : 64	

It is well to remember that this table shows only the effect of a number of chemicals as to their influence in *retarding* or *checking* the germination of anthrax spores, and not at all their capacity of *killing* these spores. It is much easier to check the growth of bacteria than to kill them, especially to kill them within a few minutes, which is an essential condition of the practical utility of a germicidal agent.

The most important of all bactericidal agents, because easily procured, rapidly effective, and practical, is *heat*. It can be used in the form of—

1. The actual cautery;
2. Boiling water;
3. Steam;
4. Hot air.

The actual cautery is one of the most ancient and most effective disinfectants. It must suffice merely to mention it here, as it properly belongs to the subject of operative technique.

Of the other agents, *boiling water* deserves to be placed first of all. *As to its bactericidal value, it is known that it will kill spores of anthrax in two minutes, and will destroy the vegetative forms of any coccus or bacteria in from one to five seconds.*

Next in importance is *steam*, which, to be fully effective, must not be mixed with air, but ought to be *pure and "saturated."* Steam can be used in several ways, either *quiescent* or *moving;* it can be used under *increased pressure* or *superheated.* Of these several forms, *moving steam* has been found most useful, and it will kill anthrax spores in from five to fifteen minutes.

Less effective than steam is hot air, to which, at a temperature of 140° Celsius, spores will succumb only after an exposure of *three hours.* Another great drawback of hot air is its great inferiority of *penetration* as compared with boiling water and flowing steam.[1]

The *bactericidal* value of the commonly employed chemicals of surgery falls far below that of the caloric agents just enumerated. There are very few chemicals which even in a concentrated state will destroy anthrax spores within twenty-four hours. Of these may be mentioned—

Bichloride of mercury,
Iodine,
Chlorine,
Bromine,
Trichloride of iodine,
Cresol mixed with sulphuric acid.

Of chemicals that require a much longer time to kill anthrax spores there are—

Carbolic acid, 5 : 100.
Creoline,
Ligneous vinegar, 2 days.
Chlorate of lime, 5 : 100, 5 "
Turpentine, "
Formic acid, "
Chloride of iron, 5 : 100, "
Quinine mur., 1 : 100, 10 "
Arsenious acid, 1 : 1000, "
Muriatic acid, 2 : 100, "
Ether, sulphuric, 30 "

Among substances that even after months have exerted no influence whatever upon the vitality of the spores of the bacillus of anthrax, there are—

Absolute alcohol,
Distilled water,
Chloroform,
Glycerin,
Benzoic acid,
Ammonia,
Concentrated solution of cooking salt,
Chlorate of potass. (5 : 100),
Alum,
Borax.

These lists demonstrate the remarkable resisting power of *spores* to the various chemical disinfectants. The *vegetative* forms of pathogenetic microorganisms, the *bacilli* and *cocci*, show a much lower degree of vitality, and will more easily succumb to the effects of even the weaker chemicals. But under the most favorable conditions their effect is not nearly as rapid as that of boiling water, which will destroy the more resistant spores in from two to five minutes, while the effect of a 1 : 1000 solution of bichloride of mercury upon the much less resistant bacilli of anthrax or upon the staphylococcus pyogenes is not assuredly destructive in fifteen minutes (Geppert).

[1] Wolfhügel: *Mittheilungen aus dem Kais. Gesundheitsamt*, 1881.

It was pointed out before that the unqualified application of the results of experiment to the conditions of actual surgical practice would lead to serious error. While in experiment a small quantity of bacilli gained by pure culture and soaked into a single thread of silk is exposed to the effect of a large volume of the germicidal solution, in surgical practice enormous masses of various microbes, imbedded in solid and semi-solid tissues, sloughs, scabs, blood, fæces, grease, and dirt, are encountered by a limited quantity of the germicide. While in the experiment the germicide will penetrate, reach, and bathe every single individual of the micro-organisms, in practice—for instance, in a suppurating wound—only a very limited quantity of the vast masses of microbial matter will come in actual contact with the solution. Finally, where under experimental conditions the chemical action of the germicide is unimpaired by accidental disturbance, here, in the wound, most of the active principle of the solution will be neutralized by contact with albuminoid components of the tissues and discharges. Hence it follows that the theoretical results of experiment as to the value of this or that germicide must differ materially from those gained in actual practice.

The principal substances that frustrate the usefulness of germicidal aqueous solutions are, first, a *coating or admixture of fatty matter* impenetrable to water; and, secondly, *the albumin* contained in human tissues and their discharges, which, united with some of the strongest metallic germicides, changes them to inert albuminates and annihilates their germicidal properties.

In estimating the practical utility of the various methods of disinfection two questions are of the utmost importance: *First*, How much time is consumed by the procedure to be effective? and, *secondly*, Will not the objects to be disinfected be damaged by the process? Where the process must be accomplished in a few minutes, germicidal solutions are entirely inadequate, while boiling is perfectly satisfactory. Where metal instruments are to be disinfected, corrosive sublimate, for instance, is inadmissible, but in the disinfection of the skin of patient and surgeon boiling water would not be proper or agreeable. Thus it will be seen that the external conditions influencing disinfection are variable, and that under changing conditions a variation of the process of disinfection must take place. Often—in fact, as a rule—several of the known methods of sterilization have to be combined, their application being either simultaneous or successive. To illustrate this we may mention that the patient's skin, for instance, is first macerated, then shaved, scrubbed, freed from grease by ether, and finally exposed to bichloride of mercury; or the instruments are first soaked, then scrubbed, polished, finally boiled in soda solution, and so forth.

III. Cleansing of the Skin and of Mucous Surfaces.

The surface of the human body is a very hotbed for the propagation of a great variety of micro-organisms. With the aid of a little methylene blue it can be readily shown that the surface of the skin, even of a very cleanly person, is literally swarming with fungi, bacilli, and cocci. The predominance of this or that microbe is determined by the habits,

occupation, and state of health of the individual.[1] Hairy places, as the head, armpits, etc., and especially the immediate neighborhood of the natural apertures of the body, are very rich in microbes, which become notably multiplied whenever even a slight disturbance of the normal state of health of any portion of the skin occurs. Sweating or a slight catarrhal or eczematous condition favors the multiplication of their growth to an incredible extent, which will be still more rank in the presence of a suppurating wound, sinus, or ulcer. And, as we never can tell whether pathogenetic microbes are present or not, one of the most indispensable conditions of safe surgery is the scrupulous cleansing of the skin of the field of an operation and of the hands of those that are to come in contact with it. The surgeon's hand, having often unavoidable contact with unclean surfaces infected with pathological organisms, is a most common carrier of infection.

The disinfection of the hands is not an easy or rapid process. The slipshod methods of cleansing the hands practised in the early period of the antiseptic era, when a scrubbing even was deemed superfluous and main reliance was placed on the efficacy of the carbolic lotion, were found to be entirely inadequate. Fürbringer's excellent labors have taught us that here, as elsewhere, the action of the chemical disinfectants is accessory only, the chief importance belonging to the preparatory *mechanical cleansing*. The dry and crusted masses of bacterial dirt must be first softened by the use of a strong alkaline soap and hot water; the coatings of grease must be dissolved by the application of ether, benzine, or alcohol; then the razor and scrubbing-brush have to sweep away the masses of macerated filth. Only after the large bulk of dirt has been removed by these means will the application of a germicidal lotion be of any use. In fact, a very careful and thorough mechanical cleansing will under most circumstances render the use of germicidal lotions superfluous.

Simple as this process of cleansing seems to be, its value will depend on the conscientious thoroughness with which it is applied, which thoroughness again presents the most remarkable personal variations in various medical men. While with some few a sublimate lotion is a real superfluity, the cleansing processes of others are so shallow—in fact, a mere sham—that in their case the abandonment of chemicals would mean all forms of surgical disaster. And as long as the meaning of the canons of cleanliness will have to depend on the individual interpretation of the practitioner, the use of chemicals cannot be excluded from surgical practice.

The difference between what is termed asepsis and antisepsis is strikingly illustrated by the preceding remarks. Where mechanical and caloric measures are applicable and sufficient to the attainment of a state of freedom from micro-organisms, there we have *asepticism*. Where this is not the case—that is, where, either on account of the inherent condition of the surfaces to be dealt with, or because of the low order of the conception of purity of the medical attendant, heat and scrubbing cannot or are not used to their full extent—chemicals must be accepted as a makeshift, and the process is termed *antisepsis*.

[1] Fürbringer: "Untersuchungen über die Desinfection der Hände," *Deutsche med. Wochenschrift*, 1888, No. 48.

Among the several methods of *disinfecting the surgeon's hands*, this one can be conscientiously recommended:

1. Rub a sufficient quantity of green or soft soap into the hands and upon the bared arms; then scrub them in hot water with a stiff brush for one minute, paying special attention to the nails and the subungual spaces.

2. After scrubbing, the spaces under the nails must be carefully freed from all loose matter by the use of a nail-cleaner.

3. The hands are now immersed for one minute in strong alcohol (80 per cent.).

4. Finally, they are immersed in a 1:1000 solution of bichloride of mercury for one minute, during which this solution is to be well rubbed into all folds and creases by the aid of a brush.

There are other methods just as reliable as this one, notably that in which permanganate of potash is used; but the necessity of employing oxalic acid for the decoloration of the epidermis, deeply stained by the manganate salt, is a great drawback to its use.

Similar principles prevail in *cleansing the skin of the patient*, with some important modifications rendered necessary by unusually adherent deposits of dirt:

1. The skin is shaved, not only in the armpits, on the head, face, pubic and anal regions, but wherever an operation is to be performed.

2. Whenever possible a general bath should precede the consequent steps.

3. Where, as on the hands of laboring-men, or on the feet of people accustomed to go barefoot, or in persons of unusual uncleanliness, the deposit of dirty epidermis is very thick and massive, the parts should be enveloped for several hours in a wet pack of soap-water, by which the epidermal coating will be sufficiently macerated to yield to the scrubbing-brush.

4. Friction with water, soap and brush, and ether must then be applied until all crumbs and flakes of loose epidermis are removed and the skin becomes clean and glossy.

5. Finally, the skin is rubbed off with a 1:1000 solution of bichloride of mercury.

We cannot leave this subject without devoting a few remarks to the tools and substances used for cleansing, notably to *soap and brushes*.

Eiselsberg[1] ascertained that all forms of soap manufactured by a process of boiling are, as a rule, germ-free; on the other hand, soap produced by a cold process of blending the alkali with fats is unreliable and should be shunned.

As to brushes, it will need no special proof—though this has been abundantly furnished by Schimmelbusch[2]—that after having been used in contact with filthy surfaces, with blood, pus, and fæces, they must become charged with enormous masses of noxious germs. The destruction of these germs by chemical agents alone is uncertain and requires a very long time. On the other hand, a short boiling of five minutes in plain water or in water charged with 1 per cent. of common soda will surely render any brush germ-free. The cheap brushes made of vegetable fibre should

[1] "Ueber den Keimgehalt von Seifen, etc.," *Wiener med. Wochenschrift*, 1887, No. 29.
[2] *Archiv für Chirurgie*, 1891, pp. 163–170.

receive the preference, because brushes made of bristles are damaged by boiling. The brushes used in an operating-room should be boiled every day with the instruments. Those that were used in contact with septic material should either be set aside or must be immediately boiled before being used again. After boiling in soda solution the brushes should be kept immersed in a 1 : 1000 solution of sublimate. The brushes employed on the washstands of hospital wards or bed-rooms also need frequent boiling.

The *cleansing of mucous surfaces* with a view to their disinfection is a much more difficult matter than that of the outer skin, and here the use of chemical germicides is strictly limited by the dangers of absorption and poisoning. Hence the processes of wiping, flushing, and the *mechanical removal* of fæces or mucus, together with measures directed against the escape of fæces, bile, or urine during an operation, as by plugging or temporary ligature, will deserve the preference over germicidal lotions.

IV. The Sterilization of Instruments.

For preparing instruments for an operation their mechanical cleansing from blood, pus, shreds of fibrin and tissues, or caseous or greasy material by soap-water and a brush must be the initiatory step. Though by these means the bulk of the noxious substances clinging to the irregular surfaces of the instruments will certainly be dislodged, yet a sufficient quantity of microbes will still adhere to them to menace the welfare of the wound.[1] Hence to render the instruments perfectly germ-free something more will have to be done.

What is desired is a method that is *adequate* and *practical*—that is, not consuming too much time or injurious to the instruments.

To effect an adequate sterilization of metal instruments hot air, steam, or boiling in water can be considered. The first is impractical, as it demands special and bulky apparatus and consumes considerable time.[2] The second is objectionable, because it rusts the instruments. The third —that is, boiling—is simple, rapid, and adequate. Its objectionable feature—that is, the rusting of the instruments—has been admirably eliminated by Davidsohn's and Schimmelbusch's expedient of charging the water with cooking soda in the proportion of 1 per cent. of its quantity. The presence of the soda will not only prevent rusting, but also will render the disinfection more thorough and rapid.[3] To test this very question Schimmelbusch[4] has impregnated strands of silken and woollen thread with pus and pure cultures of staphylococcus pyogenes aureus, of the bacillus pyocyaneus, and with anthrax spores, after which they were immersed for varying lengths of time in a boiling soda solution. It was found that, without exception, the micro-organisms contained in pus, as well as the staphylococcus and bacillus pyocyaneus, were destroyed in from two to three seconds, whereas the spores of anthrax which had resisted the effect of steam heated to 100° Celsius for twelve minutes were

[1] Schimmelbusch: *Berliner klin. Wochenschrift*, 1888, No. 35.
[2] Poupinel: "Sterilisation par la Chaleur," *Revue de Chirurgie*, 1888.
[3] "Wie soll der arzt seine instrumente desinficiren," *Berliner klin. Wochenschrift*, 1888, No. 35.
[4] *Anleitung zur asept. Wundbehandlung*, p. 65.

invariably killed by the boiling soda solution within two minutes. Accordingly, it may be asserted that a brief submersion, extending over a few seconds, in a boiling soda solution would under ordinary circumstances sterilize a surgical instrument, but that a boiling of five minutes will certainly and reliably produce this effect under any and all circumstances.

The eminent disinfecting qualities of the soda solution were carefully tested by Behring,[1] who found that by the ordinary processes of the laundry, during which a temperature of 80–85° Celsius is rarely exceeded, the spores of anthrax were very often destroyed in four, and certainly within eight or ten, minutes.

Aside from its eminent bactericidal power, this method commends itself to the practitioner by its general applicability. Water, soda, a pan or pot, and fire to heat them, will be found everywhere, and under all circumstances and almost anywhere can the surgeon secure a reproachless state of asepticism for his instruments. For practical purposes it may be said, then, that *one tablespoonful of the common washing soda to a quart of water, boiled for five minutes with the instruments, is the best means of disinfecting them.*

For clinical purposes, when the same set of instruments has to be used in two or three separate and subsequent operations, Schimmelbusch has

FIG. 173.

Schimmelbusch's instrument-boiler.

devised a very practical boiler heated by gas-jets (Fig. 173). The instruments are placed on a wire tray with suitable handles, which tray is immersed in the solution for five minutes, after which the instruments

[1] *Zeitschrift für Hygiene*, 1890.

can be at once placed in the tray which is to hold them during the operation. For various reasons it is good to keep them there in a bath of plain boiled water, or, better still, in a cold soda solution, quantities of which can be kept on hand.

It is necessary to add that old-fashioned instruments, provided with wooden or ivory handles, will very soon be ruined by these procedures; hence it is desirable that such only should be used as are entirely composed of metal parts. The nickel-plating of instruments can be entirely dispensed with as unnecessary. Aluminum is promptly attacked by alkaline solutions, and is not to be subjected to this form of sterilization.

The receptacles, cases, and safes for the keeping of instruments should have tight doors. They are best constructed of iron with glass panels and shelves, and should be kept closed against dust all the time.

The old-fashioned silk-lined pocket-instrument case of leather is out of date, and should be supplanted by a washable canvas case, which ought to be cleansed by boiling as often as practicable.

Aspirating and Injecting Syringes.—The disinfection of syringes and hollow needles used for aspiration and for the injection of liquids into human tissues requires special attention. The sources of infection may be here the skin of the patient, the injected fluid, and the syringe. The careful cleansing of the skin should precede every puncture, whether for aspiration or injection, as a matter of course. As to the fluids to be injected, this may be said, that Schimmelbusch[1] examined a number of standard solutions, procured either from leading drug-stores or from the wards of the Berlin surgical clinic, and found that they all contained, as a rule, large quantities of micro-organisms. Solutions of 1 per cent. of pilocarpine muriate, for instance, were swarming with bacteria; a solution of ergotine contained 10,000 germs to the cubic centimetre; and the standard solution of morphine rarely contained less than from 200 to 300 germs per c.c. Much purer were found iodoformized glycerin (10 per cent.), camphorated oil, and the watery solutions of hydrochlorate of apomorphia, of bisulphate of chinine, of antipyrine, and of the mercurial salts.

Ferrari[1] studied the behavior of various noxious micro-organisms introduced into substances used for hypodermic injections, and found that staphylococcus pyogenes aureus was instantly killed by ether, tincture of musk, and concentrated solutions of chinine—that it still lived after two hours in a 10 per cent. solution of cocaine. The same organism died in a 2 per cent. solution of morphia only after twenty-four hours, in glycerin after six days. In distilled water, however, in a 1 per cent. solution of atropia, and in ordinary morphine solutions the micro-organisms not only remained living for weeks and months, but increased and multiplied to an enormous extent.

It stands to reason that certain strongly germicidal substances, as ether, alcohol, tincture of iodine, solutions of carbolic acid and of bichloride of mercury, need no special preparation; but solutions of atropine, morphia, cocaine, and pilocarpine, which are especially prone to microbial invasion, must receive more than ordinary attention. Of these, especially cocaine is used frequently in small operations, and when

[1] Schimmelbusch and Hohl: *Anleitung zur asept. Wundbehandlung*, p. 120.

[2] "Ueber das Verhalten der Micro-organismen in den subcutan. einzuspritzenden Flüssigkeiten," *Centralblatt für Bacteriologie*, vol. iv. p. 744.

impure may lead to serious disturbances of the healing of a wound. A brief preliminary boiling in a teaspoon over a lamp- or gas-flame will be found a ready means of destroying germs contained in any of these solutions. Where larger quantities are to be preserved, an addition of a few drops of concentrated carbolic acid to, say, an ounce of solution will be found very useful. As to the syringes themselves, it must be said that they are, as a rule, easily infected and very hard to keep clean, especially those made of hard rubber and having leather washers. Koch's balloon syringe is easily cleansed and reliable, but not useful for the purposes of the surgeon, and is far surpassed by the old-fashioned barrel-syringe. Overlach has constructed a barrel-syringe which has a compressible rubber piston, glass barrel, and metal mountings. This instrument can be boiled without injury and can be easily made aseptic.

To study the value of the various ordinary methods of cleansing hypodermic syringes Schimmelbusch[1] first thoroughly sterilized an Overlach syringe, then filled it with pus, emptied it, then repeatedly filled it with and emptied it of distilled water. The number of cocci was thus materially diminished, but after ten fillings and emptyings the ejected water still contained thousands of germs. A 3 per cent. solution of carbolic acid, 1 : 2000 of corrosive sublimate, and absolute alcohol gave somewhat better results, but the best of all was squirting *boiling water* through the syringe. After the instrument was thus filled and emptied five times it was found absolutely sterile.

The hollow needles used for injection and aspiration are best disinfected by boiling in soda solution. Drawing them through an alcohol flame will certainly sterilize them, but also will destroy their temper, as they are made of steel. Platinum-iridium canulas will withstand red heat excellently, but are expensive.

V. Dressings.

In observing the course of one of the many small wounds accidentally inflicted upon ourselves with a clean instrument, of a wound left entirely to itself and not interfered with in any way, we shall get the model of repair which is the ideal aim of the surgeon. After cessation of the hemorrhage the lips of the wound become agglutinated by blood-clot, which gradually desiccates and occludes the wound in the manner of a hermetic seal. After the first smarting has passed away there will be no pain, no redness, no heat as long as the parts are left undisturbed, and after the lapse of six or seven days the dry crusted blood will peel off and the fresh sound cicatrix will come to view. Where the wound is somewhat more extensive, yet not large enough to require suture, the drying of the blood-clot is preceded by some oozing of blood-serum out of the clot. The watery part of this serum will gradually evaporate, and its solid constituents will ultimately form into a dry crust, forming a sort of protective seal both to the edges of the wound and to the clot filling it. In this case the course of healing will be identical with that just depicted, always provided, however, that the protective crust is not interfered with and that no septic matter enters the wound at any time.

Using this experience as a paradigm, the surgeon may safely imitate

[1] *Anleitung, etc.*, p. 124.

the process in the treatment of comparatively small and simple wounds, such, for instance, as occur in deligation of arteries in continuity, in herniotomy, or in the extirpation of small tumors. To ensure the stability of the relations of the several parts of a small wound we apply an appropriate number of catgut stitches; then spread over the line of union a narrow strip of gauze, and saturate this with flexible collodion, which will seal up hermetically the wound and its immediate confines. If there be no persistent and copious oozing, the wound will heal under this artificial scab without trouble. In about ten days the collodion will become loose, and, it being raised, the stitches will be found absorbed and the wound firmly healed.

But where the wound is extensive, and where the oozings are too copious to be promptly desiccated by evaporation, another method must be pursued to secure rest to the wound and to prevent infection from without. *Absorbent dressings* take their place here, and will now require our consideration.

To answer modern requirements dressing materials must possess the following qualities:

1. They must be absorbent to a high degree;
2. They must be aseptic;
3. They must possess the quality of remaining aseptic even if saturated with discharges.

Of the various materials used for dressings, *gauze* or *cheese-cloth*, first selected by Lister himself, has remained to this day the most highly prized and most universally used. Of others we may mention fuller's earth, sawdust, ashes, sand, peat, oakum, jute, tow, asbestos, spun glass, wood-wool, cotton batting, blotting-paper, and moss,—among which, however, only the last three and sawdust have a practical utility. Sawdust, cotton batting, and absorbent cotton, finally blotting-paper, may furnish very good material for extemporized dressings in emergencies. Sterilized moss (various species of sphagnum), being highly absorbent and very cheap, is, on account of the great saving that is involved by its use as against the more costly gauze, very important in hospital economy.

As to energy of absorption both as to quantity and rapidity, absorbent gauze and moss occupy the highest point. Excellent absorbent gauze can be procured now everywhere in suitable quantities and for little money. Where it cannot be bought the surgeon may easily render common unbleached cheese-cloth absorbent by boiling it for half an hour in a 5 per cent. solution of soda or in potash lye, by which process saponification of the oily matter contained in the cotton fibre is effected. The cheese-cloth is rinsed in cold water, and after drying possesses considerable though not as high absorbent power as the bleached manufactured article of trade.

The second and most indispensable condition which must be fulfilled before any dressing material is fit for surgical use is a *complete freedom from pathogenetic germs.*

Our present knowledge of the part played by noxious germs in the causation of wound diseases has fully confirmed the epigrammatic saying of Volkmann, that the human organism is not a test-tube filled with gelatin or agar-agar. We know that not every contact with noxious germs must inevitably lead to infection; but, on the other hand, we also

know how promptly the streptococcus of erysipelas, for instance, will enter the lymphatics through a superficial denudation. Hence measures at rendering our dressings germ-free must be considered important indeed.

Freedom from germs of the gauze sold in neat tin boxes by various wholesale drug firms is, though expressly guaranteed, very unreliable. And if we consider the ordinary methods of manufacture and trade, we shall not expect too much from that source. Fortunately, we have at our command ready and prompt means for rendering dressing materials aseptic.

Of these, *impregnation* of the fabric used for dressings *with chemicals* must be first mentioned. Lister's first efforts were made in this direction when he saturated gauze with a resinous mixture charged with carbolic acid. Later, corrosive sublimate displaced carbolic acid, but most of the objections justly raised against the former also applied to the latter. Aside from the fact that the ordinary processes of impregnation gave very unequal results, the objection that carbolic acid evaporated from the dressings was equalled by the fact that the mercurial salt was also evanescent, and, moreover, was liable to decomposition. Furthermore, the serious drawback became only too often evident that both of these irritated the skin, producing very acrid eczemata, and often led to more or less dangerous states of intoxication due to direct absorption by the blood. The simple fact that impregnation or sterilization was not the last, but the first, step in the preparation of the dressings, and that it was followed by more or less unavoidable handling by attendants and nurses in the course of drying, folding, cutting, and storing of the gauze, made this plan extremely unreliable.

Most of these objections disappear when we employ *heat* for sterilizing dressings. Here all the cutting and folding can be done in advance; the prepared dressings are sterilized and left until needed in the wrap or receptacle in which they were subjected to the influence of heat. Should, however, circumstances compel the practitioner to rely upon chemical sterilization, it is best to *impregnate the dressings immediately preceding their use.* Sublimate deserves the preference over carbolic acid, and the strength of the solution should be 1 : 2000.

In hospital practice, and where the conveniences can be easily procured, sterilizing by steam has much to commend it, but in an emergency *any fabric to be sterilized extempore can be made reliably aseptic by boiling for fifteen minutes in a* $1\frac{1}{2}$ *per cent. solution of washing soda in water.*

For steam sterilization excellent and simple apparatuses have been devised, their principle being mainly derived from Koch's sterilizer. In hospitals an existing steam-plant can be conveniently connected with the sterilizer, in which all the dressing materials, gowns, roller bandages, aprons, etc. needed for the day may receive their purification just before use.

The principles upon which all useful sterilizers of large size must be constructed are these:

1. The objects to be disinfected must receive a preparatory warming within the apparatus to prevent precipitation of steam.

2. The steam must enter the apparatus from above and not from below.

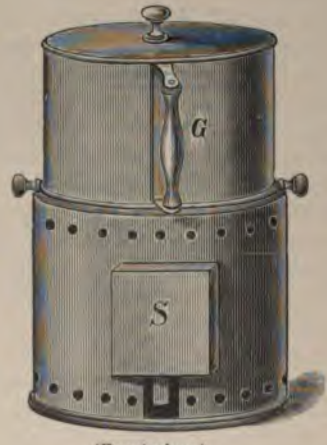
3. The steam must have a certain degree of tension.

4. The dressings must be dry when they leave the apparatus.

Preparatory warming is important, because the contact of hot steam with cold dressings will produce condensation, and the dressings will become damp or even wet. This preparatory warming is secured by a double jacket to the apparatus. Steam circulates through this and warms the contents of the central space before this is entered by steam. Gruber, Frosch, and Clarenbach have demonstrated that when steam enters the disinfecting space of an apparatus from below the atmospheric air is not driven out at once and as uniformly as when the steam enters from above. The cause of this is the fact that air, being heavier than hot steam, will naturally tend to return to the bottom of the apparatus in eddies, much of the steam escaping directly above, without uniformly permeating the entire enclosure. When steam enters from above the air is displaced gradually, uniformly, and steadily. Teuscher's observations, made on an apparatus that admitted steam either from above or from below, showed that, steam being admitted from below, the requisite temperature of 100° Celsius was reached in twenty-two minutes and twenty seconds, whereas if the steam entered from above the same temperature was registered after seventeen minutes.

A slightly increased tension, which is gained by resistance offered to the escape of the steam through the apparatus itself, is useful, because

FIG. 174.



(Front view.)

FIG. 175.

(Sectional view.)

Schimmelbusch's combined sterilizer.

it guarantees a rapid permeation of the dressings and facilitates their subsequent spontaneous drying, which will be all the prompter as the preliminary warming was thorough.

Schimmelbusch[1] and Willy Meyer[2] have described very useful small sterilizers, for the use of the surgeon in private practice, that have stood

[1] *Anleitung, etc.*, p. 84.

[2] *Med. Record*, March 3, 1894, p. 285.

the test of actual use and can be well recommended. They permit of a combined sterilization both of instruments by boiling in soda solution and of dressings in the escaping steam. For hospital use Lautenschläger's apparatus will answer admirably. Schimmelbusch's capsules or boxes, provided with a number of lateral holes which can be opened or closed by a single sliding arrangement, have been found extremely useful. The number of these boxes to be provided depends upon the amount of operative work regularly done in a given institution. All the dressings, bandages, gowns, etc. pertaining to one operation are placed in one of these boxes, which is then closed. The lateral apertures are thrown open and the box is put in the sterilizer. Having been exposed to the action of steam for thirty minutes, the box is removed from the sterilizer, the lateral holes are closed, and now the box with its contents can be left hermetically sealed until the moment when the dressings are actually needed. A large apparatus will hold six or eight such boxes, and, the handling of the dressings having all been done before sterilizing, these will come to the wound in an ideally clean condition.

FIG. 176.

Box for dressing.

It was pointed out before, that, to be admissible, a dressing must have the quality of preventing the undue multiplication of pathogenetic germs in the discharges by which it becomes permeated, or even have a direct germicidal influence upon those germs that are naturally contained in the secretions. Formerly we endeavored to accomplish this by impregnation with chemical agents, as, for instance, carbolic acid or corrosive sublimate. But the defects of this plan, developed in the course

FIG. 177.

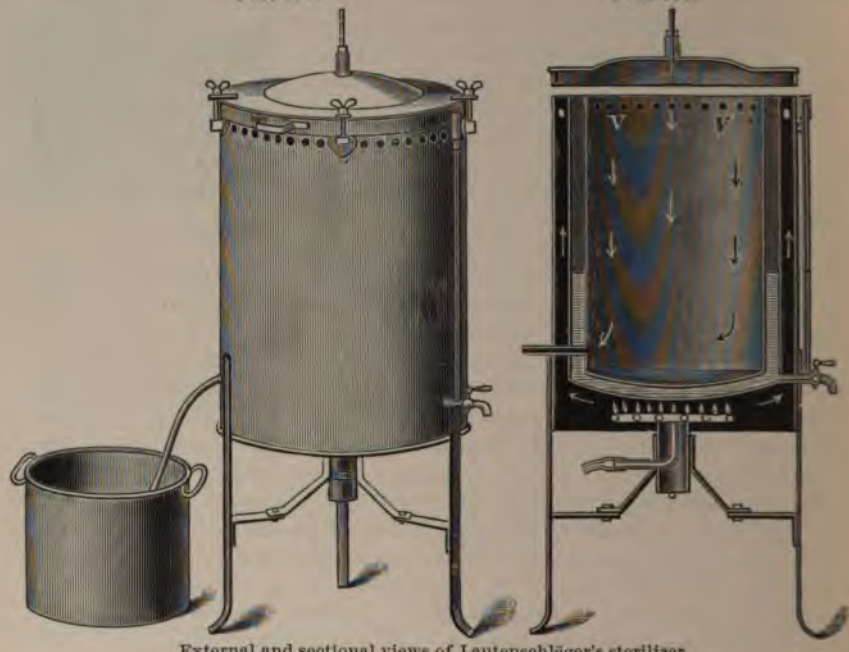
Willy Meyer's portable sterilizer.

of actual practice, and mentioned before, are so serious and important that the necessity of an improvement was keenly felt everywhere. As an expression of this must be taken the long series of trials with various chemicals, which, however, but strengthened the distrust felt toward them. Only since Neuber demonstrated that the most energetic parasiticide is

dryness—that by encouraging a rapid evaporation of the fluid part of the discharges contained in a dressing we shall check much more effectively the proliferation of microbes than by means of chemical agents

Fig. 178.

Fig. 179.



External and sectional views of Lautenschläger's sterilizer.

added to the gauze,—only since then were we able to relinquish the use of unreliable, irritating, and poisonous chemicals. Neuber demonstrated in actual practice that a dressing, however soaked full with the first discharges of a fresh wound, remained perfectly sweet for an indefinite time

Fig. 180.

Fig. 181.

Fig. 182.

Lautenschläger's sterilizer; Schimmelbusch's dressing-box.

if by rapid evaporation a drying up of the discharges was brought about. The crusted discharges thus formed a sort of aseptic seal, like

the dried blood-clot in the small wound we have used as an illustration at the beginning of this paper. Practically, the wound by this process was converted into a subcutaneous injury.

But all this refers only to fresh wounds, the discharges of which are serous, thin, and not septic. Where we have to deal with suppurating wounds, with secretions that are thick, viscid, and often contain considerable masses of decomposing detritus and slough, rapid evaporation and inspissation become a drawback. First, the dressings cannot readily absorb the discharges, which remain pent up, as it were, about the orifice of the wound. As soon as evaporation leads to crusting, these discharges become sealed, and retention with all its harmful consequences is the direct effect. Here, then, *moist dressings*, the prevention of evaporation by the use of impermeable coverings, and frequent changes of dressing accompanied by a thorough cleansing of the wound, represent the order to be followed.

Wherever, for various reasons, it is needed to pack or tampon a wound, moist treatment is preferable to the dry, and here impregnation of the packings with *iodoform* is highly convenient. The inhibitory action of iodoform upon the development of the ordinary micro-organisms of suppuration is still unexplained, but is not doubted by any practical surgeon. Mosetig-Moorhof first demonstrated its great efficacy in preventing septic processes in wounds freely communicating with the orifices of the digestive tract, notably the oral cavity. Subsequently it was employed with great success in wounds around the anus and rectum or the vagina or bladder; finally in wound-cavities of any description that required temporary or prolonged packing, ultimately even in the peritoneal cavity (Mikulicz).

But whenever iodoform is employed it must be used with caution, especially in anæmic and elderly subjects, as dangerous forms of intoxication are apt to follow its indiscriminate and unrestricted exhibition. Another drawback is the tendency of iodoform to produce in certain persons an angry eczema.

The iodoform powder itself may be the carrier of infection; hence it ought to be washed in a solution of corrosive sublimate before use. The best method of impregnation of dressings with iodoform is the mechanical one, which is preferable to that by the use of ethereal solutions, which are very apt to decompose. *Crystalline* powder of iodoform is simply scattered as evenly as possible over the moistened gauze, then rubbed into its meshes by hand. Gauze thus prepared must be kept in a tight receptacle to prevent its drying, which is still further prevented by the addition of a little glycerin to the plain boiled water used for moistening. Light will also tend to decompose iodoform; hence the powder and iodoform gauze ought to be kept in vessels that exclude light.

When iodoform gauze is badly borne, or where its use is contraindicated for other reasons, the powder of *subnitrate of bismuth* might be advantageously substituted; or the gauze might be moistened with either a 3 per cent. solution of *acetate of alumina* (Burow's solution) or a 1 per cent. solution of *chloride of zinc*.

In regard to the technique of tamponade the following hints may be found useful: The width and length of the strips of gauze used for

packings should be regulated by the shape and extent of the cavity to be filled. Each recess ought to receive a strip of its own packed down loosely and its end brought out, corresponding to the location of the recess. The end of each strip must protrude from the wound, otherwise it might become lost. When very large cavities are to be treated, it might be objectionable to use the large amount of iodoform gauze requisite for filling the space. Here an ample compress of iodoform gauze ought to be made to serve as a *lining* of the cavity, the central space being filled with strips of plain or medicated gauze other than iodoform. The oozing of serum out of tamponaded wounds is often very copious. Here the superficial dressings should be changed frequently. After the lapse of twice or three times twenty-four hours the packings have to be removed or renewed when secondary sutures are contemplated—as, for instance, from amputation wounds or the peritoneal cavity. From the mouth, larynx, circumrectal spaces, or the bladder the packings are not removed until they become loosened, unless special indications compel their earlier withdrawal. Whenever the packings of a septic wound are removed, it is well to observe a system or order in removing them. As soon as a strip is removed it ought to be replaced at once by another clean strip, then another strip is removed and replaced, and so on until the entire wound is cared for; otherwise recesses might be overlooked and thus give rise to retention. Where special precaution is demanded, as, for instance, in the removal of tampons covering intestinal sutures, these tampons must be marked by tying a knot in their distal end.

As most of the dressing material used by the general practitioner is necessarily derived from drug-stores, it would seem very desirable for the manufacturers of dressings to adopt a method of sterilization by steam, according to which the dressings, put up previously in suitable paper or muslin packages, were to be subjected to sterilization *within and together with their closed wrappings.* Thus the contents of each package would certainly remain sterile until needed.

VI. Sponges and their Substitutes.

For the rapid and thorough removal, during the progress of various operations, of blood, and in some instances of pus, sponges are indispensable. All the different substitutes that have been suggested instead of sponges lack the unique qualities of a good sponge. Its softness, the avidity with which it absorbs liquids, and the readiness with which it yields them on pressure, are all due to the incomparable elasticity and porousness of its substance. Fortunately, we have in this country a cheap and abundant supply of *reef sponges,* chiefly brought from Florida and the Bahamas. They possess all the main qualities of a good sponge, and, being very inexpensive (about $2.00 to $2.50 a pound), need not be used oftener than once in aseptic cases. Those saved from an aseptic operation can be resterilized, and are excellent for operations on septic wounds.

The difficulty of a reliable disinfection of sponges has been well recognized by practical surgeons since early times, and the search after a good method of cleansing has resulted in a number of propositions. One of the oldest procedures is as follows: The sponges are thoroughly freed

from calcareous matter by beating with a stick; are then immersed for twenty-four hours in a watery solution of permanganate of potash, 1 : 500, from which they are transferred into a 1 per cent. solution of subsulphate of soda, to which is added pure muriatic acid in the proportion of 8 per cent. of the volume of the subsulphate-of-soda solution. This bleaches the sponges and frees them of the remnant of calcareous dust. After this follows a thorough rinsing in water and immersion in a 5 per cent. solution of carbolic acid, and the longer the better, as a short immersion is often insufficient for a thorough sterilization.[1]

Kümmel's plan is very much simpler, but still less reliable. However, it would be improper to condemn it altogether, as it has been found excellent and very reliable after the addition of a few simple improvements of the method.

Gerster's modification of Kümmel's method is as follows: The sponges are beaten, then immersed for twenty-four hours in an 8 per cent. solution of muriatic acid to free them of calcareous sand. After this they are rinsed in cold water and put in a closed jar filled with water in a warm place for three days. During this time the spores contained in the meshes of the sponge all germinate, and thus become more sensitive to the influence of germicides, and hardened collections of filth are also macerated and softened. After three days the sponges are thrown into a vessel containing hot water, and each sponge is thoroughly kneaded and rubbed with green soap, which carries the maceration and softening of the dirt adhering to the meshes to such a point that most of it is removed by a subsequent rinsing in cold water. Each sponge is now dipped in alcohol, squeezed, and thrown into a jar containing either a solution of corrosive sublimate 1 : 1000, or a 5 per cent. solution of carbolic acid, in which it remains until needed. On account of the precipitation of the mercurial salt the sublimate solution ought to be renewed every few weeks. In carbolic acid, which is more durable, the sponges are apt to turn brown, which, however, does not diminish their usefulness.

The simplest and most convenient mode of disinfection by boiling in soda solution cannot be employed with sponges, as their softness and elasticity are destroyed by excessive hardening and shrinkage. Dry heat will sterilize them thoroughly, but will also cause shrinking and hardening unless the sponge is first freed from every trace of atmospheric moisture—a somewhat difficult and impracticable process.

Schimmelbusch[2] has devised the simplest and best mode of disinfecting sponges, which has stood the severest tests both of practical experience and of bacteriological scrutiny. The sponges are first freed from sand in the usual manner, then are rinsed in cold water, in which they are left to macerate for a week or so. After this they are cleansed of gross dirt by washing in warm water, from which they are taken and enclosed in a muslin bag. In the mean time a suitable quantity of a 1 per cent. soda solution is brought to the boiling-point in a pot or boiler. As soon as it is boiling freely the pot is withdrawn from the fire, and into this scalding solution the bag of sponges is immersed for thirty

[1] Frisch: "Ueber Desinfection von Seide und Schwämmen," *Archiv für klin. Chir.*, 1888, p. 749

[2] *Anleitung zur asept. Wundbehandlung*, p. 116.

minutes. The soda solution will retain a temperature of from 80 to 90 degrees Celsius for a considerable time, and this is sufficient to destroy all germs, even the very resistant anthrax spores, within ten minutes (Behring). After thirty minutes the bag is removed from the boiler, and the sponges are liberated of their contents of soda by rinsing in plain boiled water, which should be done while the sponges are still within the bag. Finally, they are placed in sublimate or carbolic solution until required for use.

FIG. 183.

Mop, a substitute of the sponge.

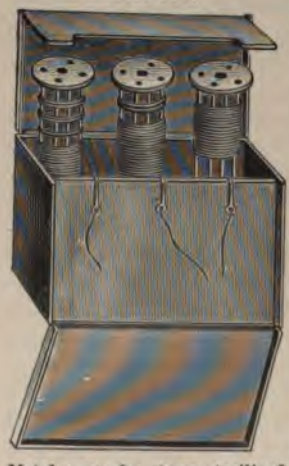
A fair substitute for sponges are the *sponging pads* ("Tupfer") used by a number of surgeons exclusively and in preference to sponges, and employed by all in emergencies. They consist either of a square piece of absorbent sterilized gauze, 10 by 10 inches, crushed into a ball, or of a smaller square of gauze, filled either with sterilized moss, wood-wool, or absorbent cotton, and tied in a neck with sterilized cotton thread.

VII. SUTURES AND LIGATURES.

The substances used for tying vessels and for the approximation of the edges of wounds by suture are either absorbable or non-absorbable.

Non-absorbable are silk, silkworm gut, cotton thread, horse-hair, and silver wire. Their sterilization can be reliably done either by boiling in soda solution or by exposure to a current of steam, the former at the same time with the instruments, the latter with the dressings. The non-irritant quality of any one of these substances depends entirely and solely upon their freedom from noxious germs, and on nothing else. Hence if they are to be buried in the tissues it is advisable to subject silk and silver wire to a thorough disinfection *just before use*. The silk employed in suturing may be sterilized once, and then preserved in a tight vessel containing either carbolic or sublimate solution.

FIG. 184.



Metal case for steam-sterilized dry silk (Schimmelbusch).

Of absorbable threads there are catgut and kangaroo tendon (Marcy). The endeavor of the older surgeons to gain an absorbable material for ligatures led to the tentative employment of buckskin, the aorta of the ox, fresh intestinal fibre, fresh tendon, and raw hide; and the great advantage of a material that, after having performed its function, disappears without any further aid, is very evident. Moreover, it is well known that many aseptically buried silk or wire threads will ultimately work out to the surface, though this may happen without active suppuration. Hence we owe a debt of gratitude to Lister, who systematically intro-

duced animal or catgut ligatures into surgical practice. Catgut, long since in use on musical instruments and in certain trades, is made of the fibrous portion of the muscularis of the small intestine of sheep. The process of maceration, by which the mucous, serous, and circular

FIG. 185.

Glass jar for wet catgut or silk.

muscular constituents of the intestinal wall are prepared for their mechanical removal, involves decomposition, and permeation with millions of micro-organisms, among which the spores and bacilli of anthrax may be and have been represented (Volkmann). Therefore a thorough disinfection of catgut becomes one of the most important desiderata of clean surgery. Of Lister's original method, of disinfection by immersion in carbolized oil, it need only be said that it is entirely inadequate, and has been universally abandoned.

Lister's chromicized catgut offers more security against infection, because chromic acid, a strong germicide, is employed in addition to carbolic acid, and the solutions used are aqueous, not oleaginous; hence much more effective. The object of the addition of chromic acid, however, was not the attainment of a more complete asepticism, but a hardening of the gut to prevent its too rapid or premature absorption.

Chromicized catgut is prepared as follows: To a 5 per cent. carbolic-acid watery solution is added crystalline chromic acid in the proportion of 1 : 4000, in which the catgut remains immersed for forty-eight hours. Then it is taken out, dried, and kept in carbolized oil, 1 : 5.

Kocher's preparation with oil of juniper has yielded good results, though it has led to failures in the hands of Kocher himself. Catgut is placed in the oil of the berry of juniper for twenty-four hours; then it is taken out and kept in absolute alcohol.

Bergmann's procedure is very reliable, and can be warmly recommended. First, the vessel to serve as a receptacle is sterilized in steam for three-quarters of an hour; then raw catgut is wound upon suitable glass bobbins, and is placed in sulphuric ether for twenty-four hours to free it from fat. Now the ether is poured off and replaced by a solution

of corrosive sublimate 10 parts, absolute alcohol 800 parts, and distilled water 200 parts. This alcoholic solution becomes turbid after a day, and should be renewed twice. After three times twenty-four hours the sublimate solution is replaced by absolute alcohol, in which the catgut is kept permanently.

The methods of sterilization by boiling and steaming are not applicable to catgut unless another medium than water is employed. Brunner's[1] process by boiling in xylol, and Dowd's in alcohol, are both complicated, and not more reliable than Bergmann's plan.

The modus of the absorption of catgut buried in living tissues has been studied by Lesser[2] and others, and consists first of swelling by imbibition; then its interstices are invaded by leucocytes, to be soon followed by granulation tissue, under the influence of which it becomes disintegrated and assumes the character of detritus, which is gradually carried away by the lymphatic circulation.

VIII. Drainage.

Since Chassaignac, who was the first to use it, systematic tubular drainage has remained firmly established in surgery. It is true that its scope has been considerably curtailed by simple canalization (Neuber) and capillary drainage; still, in the vast field of suppurative affections and in the surgery of certain cavities tubular drainage remains indispensable.

The selection of the proper form of drainage must depend upon the nature of the discharge to be drained away. Where serum, or bloody serum of an aseptic character, is to be expected, especially when the shape of the wound is not complicated and not too deep, capillary drainage by the aid of a few strands of horse-hair or catgut will be in place, or even the leaving of one or more angles of the wound slightly patulous, or the placing of sparser suture-points, will be found sufficient. Small wounds can be tightly closed without any drainage *if the surgeon's aseptic measures are perfect.* Even as large wounds as those made in amputation of the mamma have been habitually closed by the author with sutures without any drainage, and out of 29 cases, in 28 healing took place without trouble and by the first intention. But in the twenty-ninth the patient came very near losing her life by acute sepsis inadvertently carried into the wound at the time of the operation from a neighboring patient suffering from acute osteomyelitis. Before the wound was examined extensive sloughing of the fasciæ and of the outer skin took place.

From tubular drainage where thick, consistent, and ropy masses of pus are to be carried out of a cavity, to capillary or no drainage where a perfectly dry and aseptic wound treated without chemicals promises to remain dry and aseptic, the transitions and gradations are many, and their proper selection and adaptation must depend on the skill and judgment of the surgeon.

Whatever material is to be employed for drainage, it is indispensable that it should be made absolutely sterile before use.

[1] "Ueber Catgutinfection," *Beiträge für klin. Chir.* (Bruns.), 1890.
[2] "Ueber das Verhalten des Catgut," *Virchow's Arch.*, vol. 95, 1884.

Neuber's absorbable drainage-tubes, prepared out of decalcined ox-bones, and similar ones made of the long bones of large birds (Trendelenburg, MacEwen), have all been abandoned as impractical. Glass drainage-tubes are very neat and clean, and can be readily sterilized, but are rigid, fragile, and cannot be shortened to suit varying conditions; hence they have come into use only here and there. Rubber drainage-tubes are still considered the most adaptable, cheap, and useful material for wound-drainage. Their disinfection can be safely done by boiling for five minutes in soda solution (1 per cent.) or by steaming during fifteen to twenty minutes. This will not harm the rubber. After disinfection the tubes ought to be preserved by preference in a 5 per cent. solution of carbolic acid, which will not become inert by contact with rubber, as will corrosive sublimate. The best receptacle is a tall fruit-jar. The tubes should be cut into proper lengths—that is, a little shorter than the height of the jar—and are to be put in upright—that is, standing on end—to facilitate removal.

IX. Lotions, Irrigating Solutions, and Antiseptic Powders.

Water, the usual solvent in preparing lotions, is never free from germs when found in its natural state in springs, wells, running water, ponds, lakes, and the ocean. Only in the state of very deep ground-water and as atmospheric vapor is it known to be germless. As soon as it approaches the earth's surface, either from below (springs) or from above (rain), it becomes charged with micro-organisms, which are often pathogenetic. Sea-water also contains pathogenetic germs near the shores, where it mingles with the drainage of inhabited areas of land.

To be admissible for surgical use water must be freed from its microbial contents. This can be done by precipitation, by filtration, by boiling, and, finally, by the addition of chemical germicides.

Finely-powdered insoluble substances mixed with water will, on settling to the bottom, carry with them into the sediment a certain proportion of the microbes suspended in the water. The finer the powder and the slower the process of sedimentation, the better will the water be purified, but a perfect state of sterility can never be reached by this method.

Filtration by the various usual methods will very materially diminish the number of germs contained in the water from lakes and rivers. The filters of the waterworks of the city of Berlin, for instance, are so effective as to reduce the number of microbes contained in a cubic centimetre of the water of the river Spree from hundreds of thousands to an average of from fifty to seventy. Here the filtering-beds are made of gravel and sand. But even where tight porous vessels made of potter's earth (Chamberland-Pasteur) or of an impalpable powder (like Kieselguhr[1]) are used, the certainty of an absolute detention of all microbes in the filtering medium is assured only for a certain time. In addition to this, large quantities of water cannot be treated by this method in a practical manner.

Boiling is far superior to either sedimentation or filtering. Almost all of the germs contained in water are surely destroyed by boiling for

[1] Nordtmayer: "Ueber Wasserfiltration," *Zeitschrift für Hygiene*, vol. x., 1891, p. 145.

five minutes, and this applies to the dirtiest as well as to the cleanest water. Dor and Vinay,[1] who boiled the water of the river Rhone, containing an average of 33,000 germs per litre, found that only 941 of them survived the process; that is, more than 97 per cent. were destroyed. In addition to this it must be said that the germs capable of surviving the ordeal of boiling are not pathological; as, for instance, the hay bacillus. The method commends itself for its simplicity, safety, and general applicability; hence in important cases it will be good for the surgeon to provide an ample quantity of boiled water. The dipper or pitcher to be used for ladling should be boiled together with the water. In hospitals running hot water is provided from a central boiler.

But even this simple method of sterilizing water by boiling is not always applicable; therefore it is very convenient to have another, more ready way of accomplishing the same result by the addition of a chemical germicide to the water. On account of the fact that the microbes contained in ordinary pure water are widely distributed, and not collected in dense masses, hence freely accessible from all sides, their destruction by chemicals readily dissolved in the medium is not difficult. Not so easy is the disinfection of the turbid and much-polluted waters of canals, ponds, and stagnant pools located near human habitations. The cause of this is to be sought in the fact that these waters contain smaller and larger lumps of gross dirt of varying density, aggregations of organic matter teeming with microbial life. To render chemical disinfection possible, such water must be first purged of gross filth by filtration. Should this not be feasible, boiling will have to be resorted to, and will prove even here fully effective.

Where only the mechanical effect of a lotion is desired, as in many aseptic operations, the physiologically unirritant solution of common cooking salt, 6 to sterilized water 1000, will be found convenient. This solution does not cause smarting in a fresh wound.

The most effective and most useful of all chemical germicides is *corrosive sublimate*, suggested by Koch and introduced into surgical practice by Bergmann. It is a very poisonous and very cheap white, crystalline, odorless powder, readily dissolved in water and promptly decomposed by contact with metals. Hence it cannot be used for the disinfection of instruments, nor can it be kept in metallic vessels. As common drinking-water often holds in solution considerable quantities of the alkaline earths, notably lime, which eagerly decompose the mercurial salt, forming insoluble deposits, it is necessary to counteract this tendency by the addition to the solution of some acid. Either acetic or tartaric acid, or finally common cooking salt, will perform this service, a good rule being to take either of these correctives in the same proportion as the corrosive sublimate. To a 1 : 1000 solution, for instance, would be taken 1 gramme of corrosive sublimate, 1 gramme of cooking salt, and 1000 grammes of water.

Corrosive sublimate is used in solutions of 1 : 5000 for continuous irrigation during prolonged operations about the anus; 1 : 2000 and 1 : 1000 for washing septic wounds, and for disinfecting the skin of patient and surgeon; 1 : 500 for the final disinfection of bone-cavities after necrotomy to prepare them for Schede's plan of after-treatment.

[1] "De la sterilisation de l'eau, etc.," *Lyon médical*, 1889, No. 23.

A very convenient mode of preparing sublimate solutions is that by means of *sublimate tablets* sold by the drug-firms. Transportation and dosage are very easy. In the absence of tablets the surgeon will prepare a *concentrated alcoholic mother-solution*, from which the weaker solutions are made as required. A 10 per cent. solution will be found very useful and not too bulky. Two teaspoonfuls of this, added to a quart of water, will give the proportion of about 1 : 1000. For the transportation of this strong solution a glass-stoppered bottle in a wooden case will be needed.

The **symptoms** of systemic sublimate poisoning, caused by indiscriminate use, are those of an intense enteritis with colicky, often bloody, stools and salivation. Local irritation, assuming the form of an angry dermatitis, is often caused by moist sublimate dressings.

Carbolic acid, Lister's original disinfectant, forms colorless crystals when undissolved. It is volatile and strongly corrosive. Solutions are prepared as follows: The crystalline acid is liquefied by moderate heat; then water is added in due proportion. Its usual solutions are the weaker one, 1 or 2 per cent., for the immersion of instruments, for lotions and irrigation, and the stronger solution, 5 per cent., for the disinfection of septic wounds, and for irritant injections into joints, cysts, or hydrocele. This solution, freely applied to a fresh wound, will produce a grayish glaze, due to superficial corrosion of the tissues. It is very poisonous, especially to small children.

One of the first symptoms of carbolic poisoning is the characteristic olive-green coloring of the urine. It is soon followed by headache, vertigo, fainting, vomiting, irregular breathing, and a thready pulse. In severe cases coma, contracted rigid pupils, clonic muscular spasms, pulselessness, suppression of urine, and intestinal hemorrhages often lead to a fatal termination. The skin is also very sensitive to carbolic acid, often responding to its irritant action by florid eczema. Strong solutions of carbolic acid applied to small members, as the fingers and toes, often cause a dry form of gangrene.

Creolin, mixed with water, forms a milky lotion, which is about three times as effective as carbolic acid. The usual proportions are 1 and 2 per cent. Its odor is very disagreeable, but it is non-poisonous.

Lysol, like carbolic acid and creolin, is a coal-tar product. It is a poisonous, soapy liquid, which yields a somewhat less turbid solution with water than creolin, and is about as effective.

Salicylic acid (Thiersch), a good, though weak, non-poisonous antiseptic powder of white color, is intensely irritating to the nasal and bronchial mucous membranes. In combination with boric acid it forms the popular *Thiersch solution:* salicylic acid 2 parts, boric acid 12 parts, hot water 1000 parts.

Acetate of alumina (Burow's solution), a very effective, adstringent, and deodorizing antiseptic, is especially useful where the skin is very vulnerable and apt to become eczematous under the dressings. It is also much used in phlegmonous affections requiring permanent immersion or irrigation. A 1 per cent. solution is prepared by mixing 24 grammes of alum with 38 grammes of sugar of lead in 1000 grammes of water. After twenty-four hours the clear part should be decanted from the insoluble sediment.

Thymol (Ranke), a mild, non-poisonous antiseptic of pleasant odor, non-irritant, is used in the strength of 1 : 1000.

Permanganate of potash is a very soluble, mild disinfectant, and a strong deodorizer, but of evanescent effect, as it is promptly decomposed by contact with the secretions. It is used in the strength of from 1 : 500 to 1 : 2000 as a mouth-wash and as an irrigating fluid for the urethra and bladder.

Chlorine, a very powerful antiseptic, is used in the shape of *chlorine-water*.

Peroxide of hydrogen (Trommsdorff), a very strong antiseptic fluid, non-poisonous, is used in the strength of 3 per cent. for the disinfection of suppurating and ill-smelling wounds; is also a good styptic.

Certain aniline dyes, as methyl-blue and pyoktanin (Stilling), are of undoubted antiseptic value in the treatment of ulcerating and sloughing malignant new growths.

Among the antiseptic powders, *iodoform* is to be first mentioned. It is a light-yellow, crystalline powder of peculiar odor, non-soluble in water, soluble in alcohol, ether, and some oils. Its antiseptic properties are developed indirectly by contact with the products of microbial decomposition (ptomaïnes and toxalbumin). Their chemical action liberates a certain proportion of free iodine, which inhibits a further development of microbes. It is very poisonous, especially to elderly and anæmic subjects, and often is also very irritant to the skin. Its offensive odor can be effectively masked by an admixture of burnt-coffee powder and some aromatic oils. It is used for dusting the line of union of a sutured wound, and most effectively in the vicinity of the natural apertures of the human body, where perfect asepsis is not attainable. In the shape of *iodoform glycerin*, from 10 to 20 per cent., it is injected with good effect into tuberculous foci. As *iodoform gauze* it is an indispensable aid in treating wounds communicating with the oral cavity, the rectum, vagina, and bladder, in the temporary tamponade preceding secondary suture, in forming a protective dam against infection of the healthy peritoneum in operations for appendicitis; finally, in plugging irregular denuded cavities caused by various intra-abdominal operations.

The **symptoms** of iodoform-poisoning are rubescence of the skin, headache, dejection, nausea, and vomiting; in the more serious cases, sleeplessness, great frequency of the pulse, restlessness, fever, delirium, maniacal attacks, finally coma and convulsions. In these cases iodine is found in the urine, in which its presence is demonstrated by the addition of dilute sulphuric acid and fuming nitric acid, together with a small quantity of chloroform. If this mixture is violently shaken, the chloroform assumes a purple color under the influence of free iodine.

Subnitrate of bismuth (Kocher) is a good antiseptic powder, though somewhat poisonous if used in large quantities. It is a strong exsiccative.

Naphthaline (E. Fischer) is also a good, non-poisonous, but very ill-smelling, antiseptic powder.

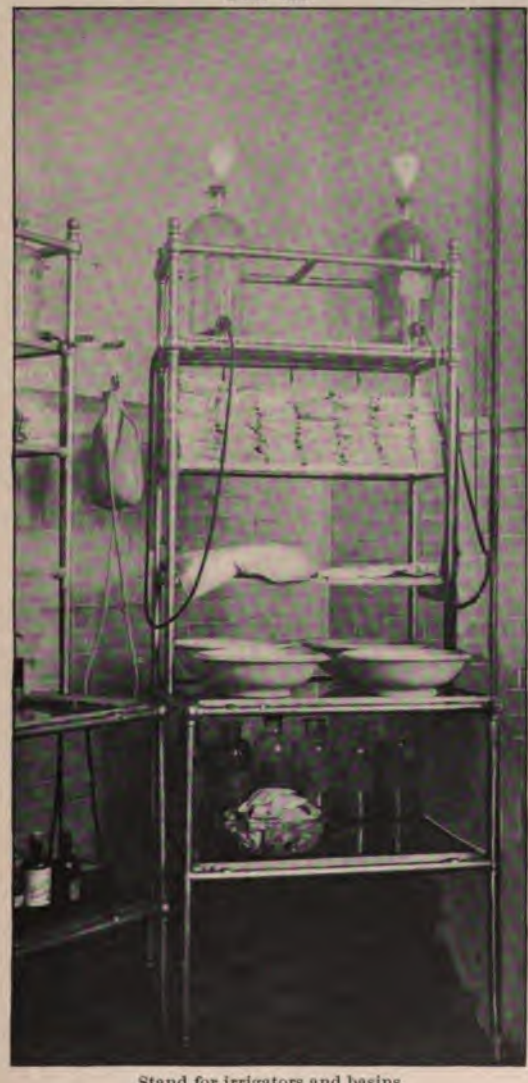
Oxide of zinc, a mild antiseptic powder, is one of the components of Socin's paste, which is used for a covering of small sutured wounds of the face, instead of regular gauze dressings. Its formula is: oxide of zinc, 50 grammes; chloride of zinc, 5 grammes; water, 50 grammes.

Iodol, sozoiodol, dermatol, aristol, sulphaminol, and *salol* are all recommended as effective substitutes for iodoform.

X. Operating-room and Sick-room.

The modern operating-room should be the embodiment of what is immaculate. Everything tending to the generation and accumulation

Fig. 186.



Stand for irrigators and basins.

of dirt and dust should be banished from it. A tiled floor, a tiled dado, the simplest and easily cleaned wash-basins, the upper part of the walls

finished in enamel paint, without cornices, angles, or projections of any kind—in short, everything of a nature admitting the easiest and most radical cleansing by scrubbing-brush and the watering-hose—are necessary. The furniture, operating and other tables, should be constructed of iron and glass, and should be kept tidy and bright by frequent washing and the application of white enamel paint. The floor should be a gently inclined plane and water-tight, affording the possibility of an unstinted use of water. The sterilizing apparatus for instruments and dressings has to be within comfortable reach of the operating-table; the instrument-cases, constructed of enamelled iron and glass, ought to be in a side room, as the abundant use of water and steam in the operating-room, however favorable against the creation of dust, is apt to cause rusting. For the reception of soiled linen a covered and enamelled metal receptacle is to be provided; for catching pus, ichor, urine, cystic and other pathological fluids, glass pus-basins and covered buckets will be needed. All of these must be immediately removed from the operating-room with their contents, and should not be suffered to remain there longer than unavoidably necessary. The dressings should be kept in the closed metal boxes in which they were sterilized until the moment when they are actually needed for use.

For the storing and use of the various irrigating fluids an iron-and-glass stand is needed, on which are disposed suitable bottles, the contents of which can be readily brought to the wound by means of rubber tubing and glass nozzles.

An ample supply of glass vessels and trays, of smaller and larger size, for the laying out of instruments and for the rinsing of hands and sponges in antiseptic or aseptic fluids during the course of an operation, forms a necessary complement of the outfit of the operating-room.

Where the operating-room serves the purposes of teaching, the

FIG. 187.

Simple operating-table (Rotter).

benches and seats provided for the audience should be of the simplest kind, admitting of an easy mode of cleansing by the watering-hose and mop.

Separate operating-rooms for septic and for aseptic cases are very desirable, as by attending to septic cases in strictly separate rooms, furnished with distinctly separate sets of instruments, the chances of accidental infection of clean wounds will be considerably diminished. Should this dualism be impossible, and there be only one room in which laparotomies, arthrotomies, and operations for phlegmonous affections must be dealt with one after the other, then the invariable rule ought to prevail, to do the aseptic operations first, and to leave the work on septic wounds to the last.

When, in private practice, a living-room of the dwelling of the patient is to serve as an operating-room, it will be impossible to create

FIG. 188.

Table for instruments and dressings (Rotter).

conditions of such exquisite cleanliness as are demanded by, and indispensable in, the tainted surroundings of a hospital. And, luckily, they are not necessary, as it is known that the atmosphere and dust of private dwellings contain much fewer pathogenetic germs than those of hospitals. It is a good rule, however, to select that one of a set of rooms *which is least inhabited*, and not to disturb the furniture and hangings unless this —that is, their removal—can be done from six to eight hours preceding the time of the operation. In short, unless the clearing and cleansing of the room be done a good while before the operation, giving ample time for the settling of the dust, it is better simply to cover the tables to be used with clean white cloths, to wipe chairs with a wet towel, and to avoid every unnecessary disturbance of the rest of the furniture that may tend to stir up dust.

Sick-rooms or *sick-wards* require a similar management; that is, scrupulous attention to cleanliness, facilitated by the practical simplicity of the utensils and furnishings. Glass and iron deserve the preference over so-called artistic furniture, and all unnecessary hangings and ornaments should be eschewed, especially where we have to deal with infectious forms of disease, as, for instance, diphtheria, profuse suppurations, typhoid and other fevers, etc. In wards the floors should be either tiled or made of terrazzo, and then covered with rugs in a suitable manner, or, if they are to be of wood, the work should be close-jointed and the sur-

face kept bright and highly polished or covered with a frequently-renewed coat of paint.

Abundant and comfortable bathing provisions form an indispensable concomitant of properly furnished wards and sick-rooms.

The *change of dressings* is an important function involving some risk, and therefore must be surrounded by adequate safeguards. The first one of these is the strict separation of patients with infected wounds from those whose wounds are aseptic. Should this be impossible, then the clean cases ought to be attended to first, the infected ones attended to the last in sequence. When there is a great accumulation of patients, many of whom require the change of extensive and bulky dressings, it is very desirable, for many reasons, to have a separate room, a so-called "dressing-room," for the renewal of all larger dressings, or, in the absence of this, to change dressings in the operating-room. The advantages accruing from this plan are—first, the avoidance of excitement among the rest of the patients, who witness the fear and outcries of the individual whose dressings are being changed; secondly, small corrections of the state of the wound, such as incisions, dilatation of sinuses, etc., can be at once performed as required, and more readily than in the wards; thirdly, the soiling of the floors and bedding and the raising of dust from the dressings removed are avoided in the wards.

Another safeguard, too often neglected in our hospitals, is this: that surgical rounds, necessitating the exposure of wounds, should not be made directly after the methodical sweeping and dusting.

Every year at least once, but preferably twice or three times, each ward should be completely cleared of patients and furniture, and receive a very thorough cleansing by the scrubbing-brush, soap, whitewash, and fresh paint. No great reliance should be placed in this annual house-cleaning upon chemical methods of disinfection, as, for instance, fumigations with sulphur, chlorine, or sublimate, or washings with antiseptic lotions. As it is known that the germs of infection are imbedded in gross masses of dirt encrusting the surfaces of walls, floors, door-knobs, furniture, etc., the rational thing to do is a thoroughgoing *mechanical cleansing* of all these articles with hot soda-and-soap solutions and by the scrubbing-brush, to be followed by the application of a fresh coat of paint. Such a radical cleansing of a ward or sick-room might be rendered necessary at any time by the appearance of erysipelas or other forms of infection with an epidemic tendency.

XI. Aseptic and Antiseptic Operating and After-treatment.

To illustrate in a coherent manner the progress of an aseptic operation we shall take as an example the account of an amputation of the female breast.

Assuming that the operation is to be done in the middle of the day, the patient should receive only a light liquid breakfast early in the morning. The operation should be preceded by a full bath if possible, and a careful shaving and scrubbing with soap and water of the field of operation, which then should be enveloped in a moist pack of towels dipped in a weak sublimate or carbolized solution. After this a clean

set of under-clothing is donned by the patient, who is now ready for the operation. As a matter of course, on the day preceding the operation a laxative is administered.

In the mean time, the operating-room is prepared. The instruments to be used are boiled and arranged in glass trays filled with a weak carbolic solution (1 or 2 per cent.), which, like all the other utensils, are placed on glass tables previously spread with clean sheets. Ligatures, sutures, and the thermo-cautery (its handle wrapped with sterilized gauze), are put conveniently in readiness. Likewise enamelled or glass basins containing a 1 : 2000 solution of corrosive sublimate, or, when the abdomen is invaded, boro-salicylic solution, are prepared for the frequent rinsing of the surgeon's hands. A suitable number of sterilized sponges are thrown into a clean glass basin, alongside of which stands another basin filled with hot sterile water for rinsing them of blood. The dressings are arranged on another table in the closed receptacles within which they were steamed,

FIG. 189.

Operating-habit of surgeon.

FIG. 190.

Operating-habit of nurse.

or, should steaming be impossible, are cut and folded in the order in which they are to be applied to the wound, and are then wrapped in a clean towel ready for use.

Before touching any of the appurtenances of the operating-room the surgeons and nurses divest themselves of their ordinary wearing apparel, which notoriously contains large quantities of dust and dirt, scrub and disinfect their hands in the manner formerly described, and don clean, well-sterilized operating-gowns made of strong linen or duck

FIG. 191. FIG. 192.

Aseptic chloroform mask of Schimmelbusch.

(Figs. 189 and 190). Where the operator has to work in the sitting posture, as in rectal and urethral operations, he wears a rubber apron underneath the linen gown. These measures should all be carried out

FIG. 193.

Applying aseptic cap (first step).

with due thoroughness, but without *finicky* exaggeration. Finally, the hands are once more washed immediately before the beginning of the operation.

The patient is now anæsthetized. The metal frame of the chloroform mask to be used must be previously boiled, then covered with sterilized

gauze. Ether masks are more difficult to cleanse, but they can also be rendered safe by dipping the mask for ten minutes into hot soda solution having a temperature just below the boiling-point. The sponge in Ormsby's apparatus ought to be renewed for each separate anæsthesia. The gags, tongue-forceps, sponge-holders for wiping out the fauces, the hypodermic syringe—in short, all the utensils of the anæsthetizer—should be rendered aseptic before use. During the progress of the operation it is the duty of the anæsthetizer to manage the head of the patient so as not to have vomit and saliva contaminate the wound.

As soon as the anæsthesia is complete the *hair of the patient* is freed of hairpins, is arranged on the top of the head, and is enveloped in a cap made of a towel wrung out of sublimate solution, which, again, is secured by a few turns of a narrow bandage (Figs. 193, 194, 195).

FIG. 194.

Applying aseptic cap (second step).

Now the patient is placed on the operating-table, and the field of operation, being exposed, is once more subjected to a thorough scrubbing with hot water and soft soap, followed by washing with ether and a

FIG. 195.

Aseptic cap *in situ*.

1 : 1000 solution of corrosive sublimate. Only the field of operation remains exposed, the rest of the body being protected by flannel leggings, blankets, and rubber sheets, which in turn are covered close up to the

limits of the field of operation with sterilized towels. These prevent accidental contact with non-sterilized parts of the body of the patient, and enable the surgeon to rest his hand and arm or to lay down an instrument without fear of infection.

Now the operation begins. Each assistant and attendant ought to know precisely what his duties are: these ought to be performed quickly, promptly, but without haste, in an orderly, systematic manner, and with such an intelligent steadiness that their constant and detailed supervision and control by the operator ought to be unnecessary. Especially in unexpected and critical emergencies no panic should be tolerated, as this usually leads to gross violations of aseptic discipline. But in this matter the operator himself must lead by good example. Whenever it becomes necessary for any one engaged about the wound to touch an undisinfected object, a careful recleansing by soap and brush and redisinfection must follow. Especially important is this rule if the surgeon's fingers come in contact, accidentally or intentionally, with septic surfaces, as, for instance, when a digital exploration of the rectum or oral cavity is done for this or that purpose. The hemorrhage is stilled by the application of hæmostatic forceps until the breast and the axillary contents are removed; then each vessel is carefully tied with catgut and the wound is filled with dry sterilized gauze to check capillary oozing. *No irrigation whatever is employed*, as it only tends to irritate the tissues.

The suturing of the edges of the wound is begun and carried down from the median angle toward the axilla, into which a drainage-tube is now inserted through a buttonhole made from the posterior aspect of the latissimus muscle; the gauze packing is withdrawn, leaving a perfectly dry wound; and the suturing is completed from end to end. As soon as the wound is closed, constant pressure is exerted upon the wound-cavity by sponges in the hands of the assistants. The bloody towels used for protection are removed, the patient's skin is cleansed, and the dressings are now applied so as safely to enclose the wound, at the same time exerting a moderate degree of elastic pressure. First comes, next to the wound, a

FIG. 196.

Completed dressing after breast-amputation (Gerster).

strip of sterilized rubber tissue protective, then a strip of iodoform gauze, then a generous padding of crumpled loose gauze balls to fill up the hollows, finally a number of large gauze compresses far overlapping the edges of the wound in all directions. Now projecting parts, the other breast and axillary margins and the corresponding arm, are covered with strips of absorbent cotton (previously prepared in the shape of roller bandages), and the whole mass of dressings and the arm are included in as many turns of a sterilized muslin roller as necessary. The patient is provided with clean warmed clothes and is placed in bed (Fig. 196).

The endeavor of every well-trained modern surgeon must be to arrange the wound at the time of the operation and while the patient is under the influence of the anæsthetic in such a manner, if possible, as to accomplish primary and uninterrupted union without any further interference. To do this a number of indispensable conditions must be fulfilled in addition to surgical cleanliness.

First. There must be a very thorough attention paid to the stoppage of hemorrhage. All bleeding points must be secured by ligature, and the use of irritating chemicals upon the raw surfaces must be avoided, as it tends to dissolve thrombi and to cause profuse capillary oozing. It is true that a perfectly aseptic wound ought to behave like a subcutaneous injury—for instance, like a fracture—but it is just as true that even the most scrupulous endeavors at asepticism will occasionally fail on account of various accidental influences. Although we know that a really aseptic, artificially-closed wound may and often does heal without suppuration, even if it be distended by a massive blood-clot, we know, on the other hand, just as well, that should an however minute infection have taken place, the microbes deposited in the blood-clot would not only find a favorable pabulum for their development, but that the direct germicidal effect of the fresh circulating blood and of the living tissues separated from the microbes by the clot could not be exerted; hence breaking down and suppuration would inevitably follow. A massive blood-clot in the wound is dangerous because it serves as a culture medium to accidentally-entered microbes, and because it prevents contact of the living walls of the wound. It must be added, however, that as we are better able to produce really aseptic wounds, so in proportion the danger from this source is diminishing. Were this not so, then a *healing under the blood-clot*, as observed in irregular hollow wounds treated according to Schede's method, would be an impossibility.

The second desideratum in the treatment of fresh wounds is the prevention of the accumulation and retention of bloody serum. This also is a good pabulum for the growth of micro-organisms and tends to separate the walls of the wound and to create tension. To prevent this disturbance we have to establish effective drainage, especially in deep, sinuous wounds and in those the walls of which cannot be kept in actual contact by external pressure or by buried sutures. Whether the means of drainage should be a gauze wick or a drainage-tube, or merely the leaving open of an angle of the wound, or sparingly-employed sutures, —this must be left to the skill and judgment of the surgeon. The selection of the site of the drainage is also an important one, a dependent situation being preferable. Good drainage will keep the wound dry and empty—will permit its walls to remain in close contact. It will prevent

the retention of fluids prone to serve as a hotbed for the propagation of noxious germs. But here, as in regard to hæmostasis, it may be said that the more perfect the surgeon's aseptic skill, the wider will become the margin of cases in which he can dispense with formal drainage.

The third requirement is *not to tear and bruise the wound-surfaces.* The rough handling due to inadequate external incisions and the so-called *blunt methods of preparation* necessarily damage the tissues much more than the clean and easy stroke of a sharp knife. The slightest infection carried into such damaged tissues must result in their destruction by suppuration, while it might have been overcome by the undiminished energy of the circulation of viable tissues. But even this generally sound rule admits of exceptions, as we know that a perfectly aseptic wound will tolerate and permit not only encapsulation of dead organic substances, but also of inorganic material. As a proof of this statement may serve the behavior of the average buried pedicle cut off from circulation by a ligature.

A fourth requirement is *intimate contact* not only of the edges of the external wound, but of all the inner surfaces. Superficial and deep-buried sutures and external elastic pressure by suitable bandaging of the dressings must accomplish this. Perfect *rest of the wound* in the condition created by the surgeon must be further secured by splints and other means of fixation according to necessity.

The last condition of success is the prevention of any *interference with the circulation* of the parts bordering the wound by too tight bandaging, false position, or other influences.

Where all of these conditions can be fulfilled without the necessity of leaving in the wound any foreign unabsorbable substance, the ideal of modern wound-treatment—that is, *healing under one dressing*—will be the gratifying result. And it affords the surgeon much pleasure to observe that the limits of this ideal treatment are being safely and steadily widened all the time.

When Neuber first advanced the principles of strongly absorbent exsiccating dressings, which were to be left undisturbed until the wound was healed, many surgeons were unwilling to try the new method, fearing to forego the precaution of inspecting the wound at frequent intervals. But the great safety of Neuber's "permanent dressing" (Dauerverband) has been abundantly proven. It is universally accepted now, and we have learned to estimate with great accuracy the exact condition of a wound without actual inspection. From this new experience was drawn the fundamental rule of *never disturbing a dressing without a clear and urgent indication.* Let us first see what is the course of events when a wound heals without disturbance of the natural process. Immediately following the operation there will be some restlessness, nausea, even vomiting, due to the anæsthetic, and later on complaints of pain, which will need some attention. But on the day following the patient will complain much less, and his general aspect will be a favorable one. The temperature, often subnormal directly after the operation, will have risen somewhat, occasionally even as high as 103° F., but the patient's general condition and *morale* do not proclaim him to be sick. The assumption that every aseptic operation ought to be followed by a feverless process

of healing is misleading, and does not correspond with actual facts acknowledged by honest observers. Almost every subcutaneous, hence perfectly aseptic, fracture is followed by some fever, which occasionally rises as high as 105° F. Volkmann made carefully-recorded observations on a series of fourteen subcutaneous fractures of the thigh. Eleven of these had fever, three had none. Mostly the fever continued for three or four days, with elevations of the temperature to from 103° to 105° F. Two patients were feverish for ten days, one for eleven, another one for sixteen days. But all of these patients, though their faces were flushed, were not ill in the least; they were simply going through an *aseptic fever* due to the absorption and elimination of the *fibrin-ferment* furnished by the extensive blood-clot surrounding the place of fracture. This fever interferes in a very slight degree, if at all, with the well-being of the patient; it generally *begins almost immediately* after the operation, and gradually subsides into a normal state of health. Volkmann was not far from the truth when he stated that about one-third of all patients treated successfully according to the aseptic plan were feverless, one-third had moderate fever, and the last third high fever.

When moderate or even high fever is observed, beginning slowly after an operation, but not accompanied by severe disturbance of the general well-being, when at the same time the pain in the wound is clearly diminishing *and the pertinent lymphatic glands do not become tender to touch*, the surgeon is justified in assuming that the wound is doing well and the dressings need not be disturbed.

When, on the other hand, the fever is due to septic infection, it generally sets in on the second or third day. While absorption of the fibrin-ferment begins immediately following the formation of clot, the proliferation of septic germs must reach a certain extent before they can provoke any serious systemic disturbance. Therefore, whenever an infection of the wound has taken place, the septic fever, usually ushered in by a rigor and followed by the well-known appearances of general intoxication and local inflammation, rarely sets in before the third day. While aseptic fever generally subsides by the fourth day, septic fever continues until a healthy condition of the wound is established.

A change of dressings should take place under the following indications only:

1. If the dressings appear to be thoroughly soaked with discharges;
2. Whenever it becomes necessary to remove drainage-tubes and stitches;
3. Immediately when a well-grounded suspicion arises that the wound has been infected.

Very often, after a large operation, especially when Esmarch's bandage has been used, a limited area of the dressings becomes permeated with blood or bloody serum. This does not necessitate a change. It will be sufficient under these circumstances to dust the soiled spot with iodoform and to bandage one or more clean compresses of absorbent gauze over it. Should the entire dressing become wet with bloody serum, only the superficial dressings need be changed. The iodoform compress which forms the immediate covering of the wound ought not to be disturbed under these circumstances.

Should the dressings become soiled from without, especially by faeces and urine, a change will be indispensable.

Silk sutures and rubber drainage-tubes are foreign bodies that must be withdrawn as soon as their office is fulfilled. The oozing of bloody serum from an aseptic wound has generally ceased after seventy-six hours, and the agglutination of the sutured edges of a healthy wound is by this time also secured. But as the vital processes are somewhat slower in some than in other persons, it will be safest to remove both sutures and drainage-tubes by the fourth day. When on inspection the wound is found normal, the tube ought to be withdrawn at once and for good. When a clean and firm blood-clot is found occupying the hollow of the withdrawn tube, this gives a safe assurance of the asepticity of the wound, which does not need any further drainage. Should there be any doubt on this point, however, then it will be wiser to replace the tube until the doubt is dispersed. *The idea that tubes irritate wounds is entirely fallacious:* tubes become irritant only when pyogenetic germs are carried by them into the wound, which may occur when they are replaced after having been infected outside of the wound by contact with filth. If things prosper, a drained wound may be entirely healed under two or three dressings.

This normal proceeding and course of healing is the rule in the majority of wounds caused by the surgeon. It will be proper to devote a few remarks to the exceptions.

Occasionally tissues are invaded which are very vascular, and from which, though the larger vessels were all secured, a profuse capillary oozing will continue for a long time. To check this oozing the surgeon must resort to *packing*. Or, to take another example, a large vein is accidentally injured in a place where the application of a ligature is impossible, as, for instance, about the intracranial sinuses. Here also packing is the only remedy.

In the first case, where cessation of capillary oozing only has to be waited for, the packings can be withdrawn in forty-eight hours. The wound will be found dry, and just as fresh as it was before packing. It can be treated as a fresh wound—that is, sutures are to be applied—and in most cases it will behave like a fresh wound and will heal by primary adhesion. After excisions of a joint, especially that of the hip, operations for vascular tumors, and some amputations, this form of treatment will yield excellent results.

When a large venous trunk has to be occluded by packing, it will not be safe to disturb the plug before either a solid thrombus has formed or adhesion of the compressed walls of the injured vessel has taken place. This will rarely happen in less than a week, after the lapse of which the plug will become loosened and can be removed without fear.

In operations about the oral cavity, pharynx, and larynx, as well as the rectum, contact of the natural discharges with the wound-surface will lead unavoidably to infection and serious mischief. This contact cannot ever be absolutely prevented, but it can be materially modified as to its consequences by judicious packing. We see after an excision of the jaw or tongue, for instance, that a properly-plugged wound does not become infected, inflamed, and fœtid, though the tampons are more or less soaked with saliva, blood, or vomit for a week or ten days.

Finally, it is necessary to mention another class of wounds in which treatment by packing yields excellent results. These are wounds *the asepticity of which is a matter of doubt;* for instance, the wound after excision of suppurating lymphatic glands or a suppurating tuberculous joint. Here the surgeon would run great risk by closing the wound. Temporary packing will be much safer, as it affords excellent and most abundant capillary drainage, by which all infectious material that might be lingering in the wound is carried away, and the plugs themselves exert an antiseptic action.

Prolonged packing without detriment to the wound became a recognized method only after the wonderful qualities of *iodoform* were clearly understood and appreciated. Whatever the chemism may be by which iodoform develops its antiseptic properties, no surgeon of this day has any doubts about them. By the aid of iodoformed tampons severe hemorrhage can be safely controlled without compromising our chances for the healing of the wound by primary adhesion; and, finally, wounds of doubtful asepticity can be rescued by the same process from suppuration.

By mentioning this last contingency we have trenched on the field of *antiseptic technique*, which must now engage our attention. Wherein lies the difference between aseptic and antiseptic management?

Asepsis is the technique by which a primarily clean and germ-free wound is maintained in its original condition; *antisepsis*, on the other hand, is the procedure the object of which is the destruction and elimination of noxious germs that have found lodgement in the human tissues and are damaging them.

Let us now examine the agencies by which a septic or infectious process established in the human tissues can be stopped. The agencies that can come in question are—

1. Thermic;
2. Chemical;
3. Mechanical.

The power of the *actual cautery* to stop various forms of progressive ulceration is a fact known to the oldest surgical writers. It is based upon the destruction of all or most of the pathogenetic germs causing the ulceration, together with the tissues within which they have proliferated. Tissues and germs are converted into a dry eschar, which remains for some time an unfavorable breeding-place for any germs that might have escaped destruction by the red heat. Chancres, lupoid and tuberculous ulcers, even hospital gangrene, are all amenable to the action of the actual cautery. The field of its application is limited, but where it can be employed it is very trustworthy and entirely safe.

Chemical means of absolutely stopping a progressive septic process must be employed in such a manner as to imitate the action of the actual cautery. Weak solutions will certainly lave and cleanse, even disinfect to a limited extent, the *surface* of an inflamed septic area, but the deeper and deepest portions of the infected mass of tissues will not, and cannot, be influenced in the least by a weak application, temporary or even permanent. To influence a carbuncle, for instance, a mild external application of any disinfectant will be utterly useless. Infection of new areas and necrosis of the affected tissues will go on through the entire thickness of the diseased skin. *To stop the process in its inception by chemical*

influences the entire area of infected tissues must be destroyed or converted into a dry eschar. So, for instance, the spread of a carbuncle can be stopped very promptly by the corrosion of the incipient focus throughout its whole extent and depth with dry bichloride of mercury, or a paste of chloride of zinc, or by chromic acid or nitric acid. Just as the actual cautery, so these chemicals, to be effective must include in their grasp everything that is diseased. *Should a portion of the infected area not be included in the eschar, the disease will continue to advance.* Where the escharotic has destroyed all of the infected mass the fever and the local irritation will diminish or cease at once.

Where very extended areas are involved the application of chemical escharotics is forbidden on account of their poisonous effect.

We have seen that escharotics, however reliable and excellent, admit only of a limited application; further, we have shown in former sections of this paper that the influence of weaker solutions of the useful germicides is very superficial, non-penetrating, and is furthermore restricted by the danger of poisoning by absorption. Let us now examine what further means the surgeon possesses for the elimination of septic material from the tissues of the human body.

Here, as well as in the practice of asepsis, *mechanical measures are of the first and utmost importance.* By mechanical measures we understand—

1. *Incisions.*—Their object is first *to relieve tension.* To do this they must be very ample and free, and should penetrate that layer of tissues beneath which is situated the cause of tension. In osteomyelitis the periosteum and cortical layer of the affected bone must be laid open to relieve tension; in subfascial phlegmon the fascia, in glandular phlegmon the glandular capsule, must be freely split to give relief. Very often in the most malignant forms of deep-seated phlegmonous inflammation free and deep incisions for the relief of tension are urgently indicated very long before any defined abscess and fluctuation could develop. To wait for fluctuation in these cases means simply a sacrifice of the patient. If an early and ample incision is made in a bad case of deep-seated phlegmon—for instance, in Ludwig's angina—the knife will divide a nearly bloodless, recently necrosed, intensely fœtid and septic mass of indurated tissue, from which no pus, only a limited quantity of ichor, will escape.

The second object of incisions is the *evacuation* of liquid, semi-liquid, and solid products of suppuration. More or less thickened pus, shreddy and often considerable masses of necrosed fascia, must be evacuated. To aid the first evacuation of abscesses *irrigation* of the cavity may be employed. As the mechanical effect of the irrigating stream is the one we want, its chemical effect being insignificant, irrigation must be based on correct hydrostatics, which will enable a *strong current* of solution or plain boiled water to sweep through the cavity, carrying with it all the pus and detritus. Two incisions (counter-incision), or, where only one incision is feasible, the introduction of two parallel drainage-tubes, one used for the influx, the other for the outflow of the irrigating fluid, will be more efficient than one single tube. *Irrigation through a single tube ought to be done cautiously, so as not to cause over-distention and rupture of the walls of the abscess-cavity*—a warning especially to be heeded in

abscesses near the peritoneum and pleura. Evacuation of an abscess should never be aided by squeezing and pressure, as they are barbarous and might lead to further and serious infection.

Drainage of abscess-cavities through incisions by means of rubber or glass tubes or a gauze packing *is important, and is indicated as long as the walls of the cavity continue to shed effete or dead material.* The tubes should be ample and should occupy the most dependent position, so as to carry away the discharges by the aid of the force of gravity by the shortest and most direct route. They must be placed so as not to be liable to be expelled, and should not impinge on nerves or vessels. Their daily cleansing and revision—to extract large masses of sloughing tissues, for instance—are imperative. Likewise, *inspissation* by evaporation at their external orifices *must be prevented by means of moist dressings*, otherwise retention might ensue in spite of drainage.

As soon as the discharges become serous and limpid the cleansing of the cavity is finished, and the drainage-tubes should be removed.

Drainage by packing, usually with iodoform gauze, is indicated where the whole extent of an infected cavity must be kept patulous for some time. Where and how long this has to be done cannot be discussed here, and must be looked up elsewhere.

A very important aid to drainage is *posture* of the body or a limb, by which not only the efflux of discharges may be facilitated, but also impediments to the circulation may be counteracted or even eliminated.

A well-drained wound does not need either squeezing or irrigation. Where proper drainage is impossible for anatomical reasons, irrigation, occasionally frequent, sometimes even permanent, must make up for the defective drainage. Non-poisonous substances, as salicylic acid or acetate of alumina, are the only ones that ought to be used for this purpose.

As long as the cleansing of an incised and drained focus has not been manifested by the cessation of fever, pain, and the final change of the discharge from ichorous and purulent to a bland, scanty, and serous one, the dressings should be moist and need frequent changing. As soon as the cavity is cleaned and the drainage-tubes are withdrawn a dry, evaporating dressing ought to be applied, and this should be left on for a considerable time, often to the very healing of the wound.

XII. Accidental Wounds and Emergency Dressings.

In dealing with accidental wounds our first endeavor must be not to inflict additional damage by ill-considered and hasty attempts at relief. Experience has shown abundantly that a vast proportion of all accidental wounds are aseptic, and if managed properly will heal kindly and without untoward complications. Therefore, all forms of first aid given to the wounded must be of such a character as not to compromise the possibly aseptic character of the injury.

Hasty and unprepared explorations by finger or probe are absolutely reprehensible and useless, as their ordinary consequence is an infection of the deeper parts of the wound.

The efforts of the surgeon should be directed toward a protection of the wound by an aseptic dressing, which, applied with a moderate amount of pressure, will suffice to check ordinary hemorrhage. Should

hemorrhage be profuse on account of injury to a large vessel, proximal or distal compression by an extemporized tourniquet made of an elastic suspender, or by a Spanish windlass (Fig. 197), will be sufficient to fulfil

FIG. 197.

Spanish windlass.

the immediate requirements for hæmostasis until the transfer of the patient to his home or to a hospital is completed. Should a fracture be present, the application of a splint in addition to the occlusive dressing is all that is required.

Injury of the large vessels of the neck or groin, requiring immediate pressure by the finger-tip in the bottom of the wound, is extremely rare. Here, of course, we have no choice, as time is precious and a few minutes of unchecked hemorrhage may result in the patient's death. But this class of cases is the only one where the introduction of an uncleansed finger might be pardonable.

Washing or rinsing of an accidental wound with styptics, caustic solutions, vinegar, arnica, or even the polluted water of a well, spring, river, or canal, is also injudicious, as it is useless and may carry infection into the wound. The wisest thing to do is to wipe away the blood and dirt from the vicinity of the wound, which ought then to be covered with a clean, newly-washed, and ironed cloth, fastened down with a few turns of roller bandage or firmly tied on with a handkerchief. If time and circumstances permit, sterilized or iodoformed gauze should be procured for this first dressing.

As soon as the patient is in his home or in a hospital, the permanent disposal of the indications arising from the injury will be in order. The parts will have to be prepared as for any operation according to the principles described in the preceding sections, and then the necessary operative steps can be safely taken.

Small penetrating wounds of the extremities, caused by penetration

of fractured bones or by gunshot, unless arterial hemorrhage demand local or proximal deligation, will not need anything but thorough cleansing of the neighborhood of the wound, together with an occlusive aseptic dressing.

Large lacerated and contused wounds, much soiled by contact with street-dirt, will require careful cleansing after complete exposure of all soiled recesses, followed by drainage and a suitable dressing, with or without fixation.

Under the application of these principles the results achieved by the surgeon in cases of compound fracture and of gunshot injury are excellent.

XIII. Regional Technique.

The general rules governing aseptic and antiseptic practice everywhere must be somewhat supplemented whenever certain special regions are invaded.

The careful disinfection of the *oral cavity* is a most important preparation for all operations to be done in the mouth and the adjoining hollow spaces. A foul set of teeth, accompanied by acute or chronic gingivitis, an ichorous discharge caused by necrosis—syphilitic or other—of the nasal, maxillary, or palatal bones, are serious counter-indications to any operation not imperatively needed. The extraction of decaying teeth or of sequestra, the curing of acute or chronic stomatitis or rhinitis, ought to precede every important operation to be performed in the mouth or nose. Cleansing of the teeth by tooth-brush and tooth-powder—in short, a careful oral toilette—is here indispensable. In some cases of excessively neglected oral hygiene it will be even necessary to subject the patient to a systematic preliminary treatment before attempting an operation the success of which depends on a faultless primary union; as, for instance, uranoplasty and staphylorrhaphy.

The after-treatment of many oral operations has been robbed of most of its terrors by the employment of the *permanent iodoform gauze pack*. This, though permeated with the discharges, will protect the wound most effectively against septic infection. It should be left undisturbed until it becomes loosened by the granulations, when usually the dangers of infection are overcome. It is remarkable how closely an iodoform gauze dressing will cling to the wound-surface. To pull it away before it is spontaneously loosened will not only cause considerable pain, often also hemorrhage, but will especially expose the fresh wound to septic influences, which afterward are very hard to combat.

The cavities of the human body,—namely, the *subarachnoidal space, pleura, peritoneum, and the large joints*—also require special care, as their infection is followed by most serious, often fatal, consequences.

When the *skull* is to be opened, *shaving of the entire head* is absolutely indispensable. In addition to this the scalp should be well scrubbed, and then enclosed in a wet pack, which has to remain *in sitû* until the patient is anæsthetized. After the removal of the wet pack the head is once more scrubbed with soap and water to get rid of all loose epidermis. Where a *cerebral abscess* is looked for, the exposed brain should be well protected by an iodoform gauze dam before the abscess is incised. After the incision of the abscess all shreds of pus must be carefully

washed away with a strong jet of irrigating fluid—a weak sublimate solution—before the packings are removed.

Whenever the *pleura or the peritoneum is accidentally injured* during the progress of an operation it is good practice to pack an iodoform gauze compress into the rent, to be left there until it can be closed by suture, or, if this be impossible, for a longer period of time. This packing will not only protect the serous surfaces against infection, but in the peritoneal cavity will also prevent prolapse of intestine.

Whenever accidental soiling by the escape of pus or cystic fluid or fæces is to be feared, *the field of operation ought to be effectively walled off from the rest of the peritoneal or pleural cavity by a carefully-constructed dam of iodoform gauze.* Many intestinal operations can be done entirely outside of the abdominal cavity, for which purpose it is advisable to withdraw from the belly the portion of gut to be operated on, if such a step be feasible.

All operations upon the intestine should be preceded, if possible, by a careful preparation. Systematic laxation with the administration of liquid food should cleanse and leave the bowel comparatively empty. The stomach will need siphoning and washing whenever fecal vomit exists in cases of intestinal obstruction. Likewise will gastro-enterostomy or pylorectomy need a preliminary careful toilette of the stomach. Lavage is best done with a 6 : 1000 salt solution.

During intestinal operations involving enterorrhaphy the greatest care must be exercised to prevent soiling of the field of operation by fæces. The intestinal coil to be operated on is stripped of its fecal contents by finger pressure; two ligatures—one proximal, one distal—are applied to prevent the escape of fæces, and the fecal matter still contained in the immediate vicinity of the intestinal wound is wiped away by sponges or pads of dry gauze, or, when the intestine can be withdrawn from the belly, is thoroughly flushed away in addition to wiping. Strong germicides are not to be used, as this might lead to poisoning, and the main reliance is to be placed here too upon mechanical instead of chemical processes of cleansing.

Similar are the measures of cleansing employed about the *rectum and anus.* Thorough evacuation, if possible, done both by laxatives and by enemata, is to precede all important rectal operations. Where tight stricture prevents a thorough emptying of the gut, inguinal colotomy must open the way to thorough purgation. Immediately preceding the operation a large sponge attached to a stout thread is thrust high up into the bowel, the distal part of which is now well swabbed and douched either with Thiersch's solution or with plain boiled water.

Where a rectal or anal wound cannot be closed by suture the iodoform pack will render most valuable service in protecting the raw surfaces against infectious contact with fæces and urine.

The *genito-urinary tract* is very often infected by uncleanly *catheters and bougies,* the care and management of which demand some consideration.

Urine secreted by healthy kidneys and as contained in the healthy bladder is always free from micro-organisms of any kind (Cazeneuve and Livon). On the other hand, the decomposition of urine, with the subsequent inflammation of the mucous lining of the bladder, is always the

direct consequence of the introduction of certain microbes into the viscus, either from above—that is, from the kidneys—or, much more commonly, from below and without—that is, through the urethra by uncleanly instrumentation. According to Rovsing,[1] the causative factor of cystitis is the presence of pyogenic staphylococci and streptococci. Schnitzler's[2] investigations of twenty patients suffering from purulent cystitis resulted in the finding of a bacillus in thirteen of these cases, which he named *uro-bacillus pyogenes septicus.* All of the organisms causing cystitis are anaërobic; hence they are not identical with the germs that induce the decomposition of voided urine.

Fortunately, the introduction of septic germs into the healthy bladder is not always and necessarily followed by cystitis. Ordinarily, a moderate amount of noxious germs accidentally introduced in the bladder will be promptly removed with the urine. Infection will take place much more readily where morbid conditions—as, for instance, stone or a tumor—are present; and these are the very instances in which instrumentation of the bladder is demanded. On the other hand, it must be clearly stated that, both according to the experience of practice and according to the results of experiment (Schnitzler), the simple introduction of pathogenetic germs into a perfectly normal bladder may be followed by very virulent cystitis. Therefore we are morally bound to exercise the utmost care and cleanliness where catheterism of the healthy bladder becomes necessary, as, for instance, immediately following rectal operations.

Bougies and catheters may be made of metal, of flexible or hard rubber, and, finally, of a flexible material consisting of a webbed textile groundwork saturated with a gummy substance. As all of these instruments need lubrication, and as the lubricants most commonly employed are fats or oils, the coating of the surfaces of the instrument with fat will render disinfection by simple rinsing with or soaking in a germicidal solution absolutely worthless.

Metal instruments will readily lend themselves to the most simple and most reliable mode of disinfection—that is, that by heat. Either boiling in plain water or soda solution, or passing the instrument through a gas or alcohol flame or through the bed of glowing coals in a stove or grate, will certainly destroy all organic life contained in the hollows or upon the surface of metal catheters. Where constantly needed they can be safely preserved in glycerin or alcohol, but must be thoroughly flushed and wiped after each use. Twice a week they ought to be boiled.

More difficult is the management of *soft-rubber or Nélaton catheters.* They can be thoroughly sterilized *by immersion for fifteen minutes in a 1 per cent. watery solution of soda just below the boiling-point* without injury to their cohesion and flexibility; but this process, repeated too often, will finally make them hard and brittle. After a first disinfection by heat it is best to keep them permanently suspended in a tall specimen-jar filled with either a 5 per cent. solution of carbolic acid or a 1 : 1000 solution of corrosive sublimate frequently renewed. Before use, adherent traces of these solutions must be first removed by rinsing and flushing with boiled water, as the urethral mucous membrane is easily irritated

[1] *Die Blasenentzündung, etc.*, Berlin, 1890.

[2] "Zur Aetiologie der acuten Cystitis," *Centralbl. für Bacteriologie*, 1890, p. 789.

by either of these chemicals. After use all traces of urine must be washed away before the instrument is returned to its receptacle.

Still more difficult is the cleansing and suitable preservation of *webbed gum bougies and catheters.* They will stand neither heat nor prolonged soaking in antiseptic solutions, and, being very useful and the better grades rather expensive, a practical method for their safe management is of the utmost importance. Schimmelbusch[1] has demonstrated that *briskly-executed friction* of a webbed gum catheter or bougie during one minute with a wet compress or towel, followed by energetic rubbing with a dry sterile cloth—as, for instance, a freshly-laundried towel—*will thoroughly disinfect its surface,* even if it was previously smeared with and soaked in fœtid pus.

How to sterilize the hollow interior of these webbed catheters was unsolved until L. Farkas of Budapest constructed a small portable steam-boiler with safety-valve and conical nozzle, upon which is slipped the base of the rubber or gum catheter to be disinfected. Steam is

FIG. 198.

Catheter sterilizer of Farkas.

gotten up in a few minutes over a gas or alcohol flame, and is made to escape through the hollow of the catheter without injury to its quality.

The *lubricant* employed in catheterism also needs attention, as it may be the carrier of infection. Glycerin is preferable to fats. Both glycerin and fats or oils should be boiled before use. It is best to preserve them in metal cans or collapsible tubes that permit the escape of a small quantity only, just sufficient for one lubrication. Machine-oil cans, or for vaseline paint-tubes, will ensure against contamination of the bulk of their contents. *It is bad practice to dip the instrument into the bottle or can filled with the lubricant.*

Finally, before doing catheterism, it is important to consider *the condition of the urethra,* which, according to Lustgarten and Mannaberg,[2] regularly harbors, even in its normal state, a variety of micro-organisms,

[1] *Anleitung zur asept. Wundbehandlung,* 1892, p. 129.

[2] "Ueber die Micro-organismen der normalen männlichen Urethra, etc.," *Vierteljahrschrift für Dermatologie und Syphilis,* 1887, No. 4.

some of which, carried into the bladder by the catheter, are capable of inducing cystitis. *In the presence of a virulent urethritis catheterism is absolutely prohibited*, and even evacuation by suprapubic puncture deserves the preference.

The milder forms of urethritis do not absolutely forbid the use of urethral instruments, but any form of *instrumentation in presence of urethral irritation* is justified only under urgent indications, and *must be preceded by a very thorough irrigation of the anterior and posterior parts of the urethra.* The principal object of this is the mechanical dislodgement of the tenacious mucus (urethral threads) coating especially the recesses of the urethra.

Whenever possible the urethra, as well as the bladder itself, should be thoroughly washed out before an incisive exploration or operation is to be done in these organs. Or, if this be impossible *before*, it should be done as soon *during the progress* of the operation as access is gained to the urethra and bladder.

Normal salt, or Thiersch's, or boracic-acid solution, or plain boiled water, is to be used rather than carbolic acid or sublimate.

Since the regular employment of the preliminary toilette of the urethra preceding exploration and urethral operations, the frequency of urethral fever has been remarkably diminished.

Another important element of the preparation of the urinary channels for explorations and operations, especially where cystitis and pyelitis are an established complication, is the internal administration of certain balsamic substances and of some mineral and organic acids. By their exhibition for some time before an operation the quality of the urine may be materially improved in several ways. Its alkaline reaction may be changed to acidity, and its contents of pus may be considerably diminished. (For further particulars the reader is referred to the paper on the Surgery of the Urinary Organs.)

The *female genital tract* also needs special preparation for all forms of surgical interference with its constituent organs. The vagina, even in its normal state, serves as the habitat of numerous more or less noxious organisms, which thrive luxuriantly in the moist, warm pabulum of vaginal mucus and decayed epithelia. No thorough cleansing can be effected by an antiseptic douche alone, as this is unable to wash out all the effete material lodged in the folds and reflections of the mucous membrane. To reach a satisfactory state of vaginal cleanliness soap, hot water, and a narrow vaginal or *jeweller's brush* (Fig. 199) have to be plied energetic-

FIG. 199.

Vaginal brush.

ally until all effete material is loosened. After this it can be readily washed away by the jet of the douche.

The endometrium and lining of the cervical canal will also need a

special cleansing before any exploration or operation involving a lesion of continuity of the organ can be undertaken. If the os is contracted, it will have to be dilated to give access to the blunt or sharp curette, irrigating point, and iodoform-gauze packing. Especially when a purulent, catarrhal, or ulcerative process or neoplasm is present this scooping away of septic, broken-down material must be very thorough to prevent an infection of the peritoneal cavity. As seen by the preceding remarks, here also as elsewhere mechanical processes of depuration constitute the main portion of disinfection.

OPERATIVE SURGERY.

BY STEPHEN SMITH, M. D.

No operation should be performed, except in urgent cases, unless the patient's history and general condition have been scrupulously inquired into; even in cases demanding an immediate operation there may still be opportunity for inquiry as to previous health and habits, and to examine the heart and lungs, and perhaps the secretions of the kidneys. In delayed operations the surgeon would be culpably negligent who did not inquire into constitutional peculiarities and functional and organic affections, for the timely discovery of morbid conditions of the viscera renders possible the use of appropriate remedies before the operation. The occasional fatal results of anæsthetics are sometimes due to organic diseases of the kidneys, which by proper care might be protected from the injurious effects of these agents.

Diagnosis.—It is not always possible to discover the exact condition of a diseased or injured organ or tissue, and it is a fact of daily experience that surgeons of the greatest skill will differ in their diagnosis of the nature of a given disease, but failure to detect the more obvious and essential changes will always be construed as culpable negligence. As it is admitted that errors in diagnosis are due in a great majority of cases to haste and inattention, the surgeon should seek by thorough and patient investigation of every case, aided by the most approved instruments and appliances, to protect himself from such a charge. The elements of a correct diagnosis are found in the history of the patient, the causes and progress of the disease, and the physical examination.

1. The *history* of the patient includes the following series of inquiries: Sex, in its tendencies to special forms of disease at different periods of life and to nervous phenomena; age, as it affects the development of bones and organs, the integrity of tissues, and the occurrence of organic and malignant diseases; heredity, in the perpetuation of diseases and peculiarities of ancestors; previous diseases, which leave their sequelæ, as syphilis, scrofula; occupation, which develops special maladies, as necrosis of jaw from phosphorus; habits, with which certain affections are likely to be associated, as venereal diseases with prostitution, nervous derangements with masturbation; social condition, as it is related to secret or conjugal vices of the sexes.

2. The *progress* of the disease relates to—date of the attack or injury, on which depends the progress of the malady; alleged changes, which may be the clue to the true cause; symptoms which, taken in their order of development, give much of the clinical history and afford reliable data for a differential diagnosis; the present attitude, form, and condition of the part compared with the past; the operations which may have been

performed and their results; the course of treatment and its most important effects, which may be the very touchstone revealing the nature of the complaint.

3. The *physical examination* must be made with all necessary aids and appliances, visual, manual, and instrumental. 1. Color determines the circulation in a part; form indicates the existence or non-existence of enlargements of regions when deciding as to tumors, dislocations, fractures; translucency reveals the presence of serum, as in hydrocele. 2. Consistence must be noted in inflammatory swellings and tumors; fluctuation in collections of fluids; crepitus in fractures; crepitation in collections of air or gas beneath the skin. 3. The exploring needle detects the consistence and contents of swellings and tumors; the hypodermic syringe withdraws the fluids of abscesses and cavities; the trocar removes pieces of muscle for examination; the microscope determines histological peculiarities; the ophthalmoscope reveals the deep structures of the eye, the laryngoscope of the laryngeal passages, the speculum of the ear, the vagina, and rectum, the urethroscope of the urethra, and the endoscope of the urinary bladder. With antiseptic precautions exploratory operations may now be safely made for the purpose of accurate diagnosis.

Prognosis.—The prognosis is an estimate of the results which will follow any operation. It must depend primarily upon the knowledge obtained in the diagnosis, and secondarily upon that larger inquiry which seeks to discover tendencies and conditions affecting the ultimate issue of diseases and operative procedures undertaken for their cure. Due weight must be given to the steady improvements in the details of the treatment of wounds and the constant enlargement of the field of operations. The mortality of ordinary operations has been surprisingly reduced by the employment of means of preventing suppuration, while the range of operations is daily and rapidly increasing. The following facts are always worthy of consideration, whatever may be the operation: 1. The native bears operations better than the immigrant. 2. The sex which has the greatest endurance is the female. 3. The age is not in itself a barrier to any necessary operation;[1] however, with it we connect the most regular average difference in capacity to bear operations; the most favorable period is between five and fifteen; the next, between fifteen and thirty; after thirty the risk to life is more than twice as great as it was at the same period after birth. Young and healthy children are in danger through shock, aggravated by pain, but bear very well the loss of blood and are little liable to pyæmia after wounds. Old persons are likely to have organic diseases and degeneracies, and feeble circulation, inducing congestions, due to the sinking of the blood in the lungs, liver, intestines, and other dependent parts; are liable to die of shock or mere exhaustion, and do not bear losses of blood, lowering of temperature, or want of food; they convalesce slowly, or after partial recovery fade, waste, and die; but the thin, dry, tough, clear-voiced, and bright-eyed, with good stomach and strong will, muscular and active, bear very well all but the largest operations.

Constitutional diseases greatly modify the prognosis. In general they influence operations as follows: Scrofula gives a considerable mortality;[1] generally its ill effects are seen chiefly in the imperfect healing of

[1] Paget.

wounds, the swollen cellular tissues, the thin and lowly-organized cicatrix, or indolent ulcers and sinuses; in the large majority of chronic cases the removal of a scrofulous part is followed by improved health, but the patient remains scrofulous, and, if old, may not bear confinement well. Syphilis is liable to delay reparative action, and the operation in those who have tertiary sores may be followed by renewed tertiary symptoms; rheumatism and gout predispose to structural changes of arteries and kidneys and to organic disease of the heart; cancer contraindicates operations only in its later stages, when the general health is failing; anæmia is not a bad condition in which to operate; wounds heal slowly and soundly, but if erysipelas or like casualties supervene patients are less likely to recover.

Habits and temperament[1] should also be duly considered; intemperance increases the dangers of operations in proportion as it is habitual; slight intemperance is much worse than occasional great excesses; avoid operating on confirmed drunkards, unless compelled by the necessity of the case; operations are hazardous on all persons who require stimulants before they eat or work; over-eating is closely allied to intemperance in increasing the dangers of operations, especially if the over-eating is of meat and other nitrogenous foods; the over-fat are a bad class when their fatness is not hereditary, but due to over-eating, soaking, indolence, and defective excretions, their pendulous bellies indicating omental fat and deficient portal circulation; persons in whom the vital processes are weak, but without morbid action, repair wounds feebly, and are especially liable to diseases of the blood and tissues, and operations upon such persons should be deferred, if practicable, to some period of better health, for fear of local failure, rather than of incurring any unusual risk of life: allied to this class are the cold-blooded, with cold, damp hands and feet, dusky appearance of vascular parts, feeble circulation, small pulse, slow digestion, constipation; nervous persons, who are exceedingly mobile and excitable, whether in their sensitive or motor organs, their whole cerebro-spinal system being altogether too alert and vivacious, pass through the consequences of operations with as great impunity as any other class; malarial affections do not contraindicate operations, but in the course of convalescence ague fits, resembling those which precede pyæmia, may occur.

Deranged or diseased conditions[1] of many organs variously affect the results of operations. Of the digestive organs, gastric dyspepsia is followed only by flatulence, unless vomiting is a symptom, when anæsthetics are liable to excite emesis, with dangerous prostration; great caution is required with those whose biliary secretions are habitually unhealthy, or who have been often jaundiced, or who have a sallow, dusky complexion, dry skin, dilated small blood-vessels of the face, sallow and bloodshot conjunctivæ—symptoms which indicate deranged functions and abdominal plethora; enlargement of the liver, whether amyloid or fatty, is often coincident with chronic diseases of the bones in children, and tends to cause death either by exhaustion or secondary hemorrhage. Of the organs of circulation, affections of the heart are not serious hindrances to recovery from operations; shock and loss of blood are attended with more than ordinary risk in persons whose hearts are feeble or embarrassed by valvular obstruction, but a rapid or irregular pulse, without

[1] Paget.

organic disease of the heart, and with respiration not exceeding 20 or 25, does not contraindicate an operation; degeneracies of the arteries are only serious when general in the extremities, especially the lower, rendering primary hemorrhage difficult of control, and secondary hemorrhage more frequent and dangerous after amputation, and so interfering with nutrition that destructive suppuration is liable to occur, with slow and imperfect healing of the wound; diseased veins complicate operations only when varicose, and cut through, as in amputations, thus exciting inflammation. Of the diseases of the respiratory organs, chronic bronchitis and emphysema, especially in old people, render operations extremely hazardous, owing to imperfect respiration, cough, and loss of sleep; phthisis, when progressive, adds greatly to the dangers of operations from the consequent fever, loss of food, and pain, but, when chronic, operations are advisable which relieve the system of painful and wasting local diseases; persons suffering from long-standing strumous affections, with the appearance only of tubercular disease, may be greatly benefited by the removal of the diseased part; menstruation and pregnancy are conditions rendering operations undesirable.

Various other affections[1] often modify the prognosis as follows: Severe operations during the stage of shock after injuries and during the period of acute inflammation, with high temperature, are dangerous; spreading erysipelas, cellulitis, and gangrene add so much to the dangers of severe operations that the chances of life are best when only the ordinary treatment is followed: avoid operations in acute pyæmia when there are rigors once or more in a few days, and profuse sweatings, with very rapid pulse and breathing, and with delirium and rapid wasting, or with dry tongue and yellowness of skin, or any considerable number of these symptoms; but an operation is justifiable in chronic pyæmia when there are wasting and sweating, with the formation of abscesses here and there, and the injured part is manifestly useless and a source of irritation or of exhaustion; croup does not contraindicate tracheotomy, nor peritonitis herniotomy, which are operations of necessity, and are not materially affected by the general acuteness of the existing affections. Of the diseases of the kidney, those associated with the constant presence of albumin in the urine predispose operated patients to erysipelas and pyelitis.

Decision as to Operation.—The question of an operation enters as a new and most important element in the case, and always demands the most serious consideration, for cutting operations must be regarded as injuries, inflicted at the will of the surgeon, which may destroy a person enjoying comparatively good health, or fatally aggravate other but not serious affections. The question of operation may be involved in doubt and uncertainty, requiring for its proper solution a nice appreciation of pathological conditions, operative procedures, and reparative processes. Surgeons may honestly differ in their views as to whether an operation would produce a cure, or be of some benefit although not a radical cure, or whether the benefit would justify the operation, or, finally, whether the operation could be performed at all without destruction of life. An operation is not justifiable when the patient can be cured by any medical or other means. If the disease can be cured by a bloodless operation, as well as by one with cutting, choose the bloodless method, for the

[1] Paget.

danger is comparatively slight when the operation does not involve the injury of tissues. The object of the surgeon is twofold—viz. to save life and to promote comfort. He must never argue that life is not worth saving or prolonging. Any operation is, therefore, of undoubted propriety which is immediately necessary to save life, as tracheotomy in laryngeal obstructions, excision of poisoned wounds; or when it is less severe than other measures, as excision of small growths, instead of employing caustics; or when it is the only measure possible, as amputation of crushed limbs; or the last resort, all other suitable remedies having failed, as herniotomy in strangulated hernia. Or, if an operation promises a complete cure or long immunity from an otherwise certainly fatal malady, it is right to operate, though the procedure be severe and dangerous, as in the removal of cancerous growths. An operation is also justifiable when there is a reasonable probability that it will promote comfort, though it does not eradicate the disease, as in excising a cancerous growth. In whatever form the question of an operation is presented, all of the evidence for and against it should be personally considered by the surgeon with judicial impartiality. He should never be over-persuaded by patient or friends, nor unduly influenced by counsel, to operate against convictions deliberately formed. Neither the consent, nor even request, of the patient can justify such an operation.

The consent of the patient, or of those responsible for him, to the operation should, if possible, always be obtained. If he is not capable, as when intoxicated or comatose, or if he is a child and parents or guardian are inaccessible, operate only from clear necessity. In order that he or they may form a correct judgment, communicate the decision and the reasons that have led to the conclusion; make every necessary explanation as to the nature of the injury or malady, its probable course and termination, and the advantages, disadvantages, and liabilities of the proposed operation: thus you will discharge every obligation, and remit to the patient or friends or guardian the responsibilities of a final judgment as to the course of procedure. As far as practicable, the deliberations of the patient and his advisers should be influenced by no other considerations than those presented by the surgeon. Should the decision be favorable to an operation, the patient again returns to the surgeon's care and a new series of obligations is incurred. The preparation for the operation, its manual performance, and the after-treatment present questions which will tax his knowledge, skill, and care.

The General Preparation for the Operation.

No ingenuity of conception or brilliancy of execution of the operator can excuse the neglect to secure, by previous preparation, every possible advantage which can in any way, however trivial, minister to success; even a successful issue cannot justify the surgeon in subjecting his patient to an avoidable risk. He should strive to make the prognosis less serious and to assure the success of the operation. This result he will more certainly attain by properly preparing the patient, choosing the most favorable moment for the operation, adopting the best method of performing it, and applying the most efficient dressing.

The Preparation of the Patient.—The first care must be given to

the patient. It is important that every organ and the entire system be so prepared for the injury about to be inflicted that the issue will be favorable, for the timely discovery of morbid conditions of the viscera and the use of appropriate remedies before the operation might, in a large proportion of cases, prevent disastrous results. The effects of habits of excessive bodily indulgence in food and stimulants may be amended in a comparatively short time; previous rest, important to the recovery of the part about to be operated upon, may be secured; slight derangements, which are readily amenable to treatment, such as indigestion, constipation, diarrhœa, may at once be corrected; grave affections of the kidneys, liver, heart, lungs, and nervous centres may be so improved or the system so protected that the operation will not be serious. Even anæmic persons with feeble circulation, when suitably prepared by tonics, as iron, improve their condition and bear operations well, being singularly little liable to erysipelas, pyæmia, and other disorders of the blood. The patient should be placed under the most favorable hygienic conditions; pure air, suitable exercise, wholesome food, and undisturbed sleep are important features in the final preparation; the morale must, as far as possible, be sustained by such assurances as will secure mental quietude and hopefulness as to the result of the operation: do not exaggerate its nature, but speak encouragingly of it and of its prospective success. Finally, as a severe shock to the nervous system, produced by an exhaustive surgical operation and prolonged anæsthesia, may for a time so paralyze the stomach that digestion ceases or is greatly impaired, and the food that it contains at the moment may undergo such putrefactive changes as will render it an irritant, the food taken within six hours of the operation should be quickly assimilable and in limited quantities: milk is, in general, the best food for this purpose, especially with children, to which may be added a small amount of whiskey; a warm, well-seasoned, and well-cooked cup of broth or a fragrant cup of hot coffee and milk may be preferred by the adult.

The Time for the Operation.—The time appointed must be so fixed as to avoid the error of omission, delay—or of commission, haste—by a careful consideration of the nature of the disease, the condition of the patient, and the surrounding circumstances. It must be immediate when life is threatened and the operation offers the only chance of recovery, and should be delayed when any of the conditions enumerated would render the operation dangerous to life or abortive in its results. But not unfrequently the disease, the patient, and the circumstances combine to enable the surgeon to appoint the month, the day, and the hour. The employment of anæsthetics has so diminished the fear of operations that the surgeon may exercise his discretion as to the propriety of informing the patient of the day and hour selected.

The Place for the Operation.—In the selection of the place reference must be had to the comfort and safety of the patient. The office of the surgeon is frequently the most convenient place, but a risk to the patient may thereby be incurred, which it is better to avoid—namely, the liability of rendering a simple operation dangerous by the subsequent imprudent conduct of the patient, as exposure to the elements, excitement, fatigue, or excesses of appetite.

The room in the private dwelling should be chosen for its accessibility,

its size, and its exposure to light at the hour of the operation; the best light on a clear day for delicate operations is reflected from the northern sky. The air of the room in which an operation-wound is inflicted should be as free as it can be made from all forms of putrefactive organisms; it should not immediately communicate with water-closets and other sources of defilement, nor be occupied as a living- or audience-room. The best results, after large operations, have been obtained when the operating-room has been first purified the preceding day, and both operator and assistants have bathed and had their clothes and all the materials used about the wound thoroughly disinfected.

The Selection of Instruments.—In selecting instruments care must be taken that they are of approved utility and in good condition. The surgeon cannot employ rude articles, as a butcher's knife or a carpenter's saw, in amputation, unless he is placed under circumstances which prevent his obtaining suitable instruments. And he is required to employ the more recently devised instruments which have been recommended by the best authorities as preferable to those formerly in use, provided they are reasonably accessible to him. They should be so constructed as to be readily made aseptic and maintained in that condition. For this purpose the handle should be, as far as practicable, smooth, and made from non-absorbent material, and the setting of the blade or shaft should have no recesses for filth. They must be kept in good order, as dull knives, broken forceps, or imperfect saws seriously complicate operations. They must, finally, be kept in a state of scrupulous cleanliness, as blood and pus may convey contagion to the person next operated, and dust and filth may fatally poison a wound. The minor apparatus, also, must be carefully selected, for an operation may be spoiled by something that was thought too trivial for care.

The tests of the quality of instruments are as follows: Draw a cutting instrument from heel to point slowly across the *border* of the nail, and it will catch or stop at every "nick;" draw it across the *flat* of the nail, and if at any point the edge is seen to be wiry or smooth, it is soft, and must be reapplied to the hone; but if it becomes serrated like a fine saw, the edge is brittle and cannot be remedied by the hone. For pointed instruments stretch upon a test-drum (a contrivance for the purpose for sale by instrument-makers) a very thin piece of kid or gold-beater's skin and push the point through. If it enter smoothly and easily, the point is good; but if a slightly crackling noise is heard, it is defective. If a lancet is tested, see-saw the edge in the opening, and if it glides over without cutting or cuts roughly the edge is imperfect.

The preservation of instruments in good condition requires careful attention to the following details: Select a place always free from moisture and dirt for their safe-keeping. Polished instruments should be suspended or placed in metallic cases. After being used every instrument should be thoroughly cleaned with warm water, and perfectly dried with chamois or the fire before it is returned to the case. Silver instruments tarnish when they are exposed to the air or are brought in contact with hard or soft rubber, caustics, or acids. To preserve the edge and polish of instruments, the surgeon requires two or three small hones, some fine emery-paper, two or three screw-drivers, small files, rouge, crocus, or other polishing powder, chamois, and gold-beater's or

kid skin. Cutting instruments should have their blades kept in perfect order by the judicious use of the hone. Occasionally the blade must be ground by a competent workman. Blunt instruments, which are designed to enter natural or other passages, should be frequently polished with fine emery-paper, and then with rouge and chamois-skin, in order to remove every particle of rust and to maintain smooth, unblemished surfaces. Saws are sharpened with three-cornered files applied in the direction of the original cut of the teeth.

The case of instruments which the surgeon must provide depends upon the variety of operations which he undertakes: if limited to trifling operations, he requires only the pocket-case; if he perform minor operations, he requires the minor operating-case; if he assumes every grade of operation, be must add the general operating-case. In selecting any case the surgeon should exercise his own judgment as to the number and kind of instruments, rather than accept the list of the maker or of any other surgeon. The best assorted case contains many instruments which the general practitioner never has occasion to use. The case which immediately contains the instruments should be made of metal, and should be adjustable, so that the whole or the different parts may be placed in boiling water. Aluminum is adapted for a small case, and rolled copper for a large case.

Convalescence.—The hygienic conditions which surround a patient the subject of an operation materially affect the results. Foul air, filthy dressings, and indigestible food will thwart the best planned and executed operation. It is therefore the duty of the surgeon to secure to the patient all the advantages which healthful conditions afford. These are largely found in the room and its various appointments.

The room in the private dwelling best adapted for convalescence is on the second floor from the ground; the exposure should be to the south, with ample window space, and with opposite or partially opposing windows for thorough ventilation. The size of the room is of slight importance, except as to convenience, compared with the provisions for the outflow of foul air and the inflow of fresh air. Large cubic space does not secure purity of the air, and hence is of minor importance if the necessary amount of fresh air is supplied and properly distributed without unpleasant currents. It would, however, always be wise to provide at least two hundred feet superficial area and three thousand cubic feet of air to the patient and his attendant, each, during the first few weeks, to guard against defects in ventilation. As in private residences there are no other motors for changing the air than differences of temperature and movement of the air which can be excited by heat or wind-fans, these agents must be employed to give motion to the air. The common open fireplace, well heated, furnishes the best heat-supply for movements of the air, while the inlet and outlet of air is maintained by raising and dropping the sashes of the windows. The walls should be freshly limewashed, floors cleaned with carbolic solution; no sink for slops, nor wash-bowls drained into common house-drains, nor water-closet, should be in or communicate with the room; the furniture should be as free as possible from absorbent materials; bed- and window-hangings, carpets, and upholstery are objectionable, and if old are dangerous. Floors, furniture, and woodwork should be cleansed, without water, by rubbing

with an absorbent material. Do not place the bed near the wall, in a corner, nor in air-draughts.

The ward of the hospital to which the patient is to be conveyed should be free from suppurating wounds, erysipelas, and low forms of fever; the bed should be exposed to the sunlight, with any necessary screen for the face; it should have at least one hundred feet of superficial area and four thousand cubic feet of air; the position of the bed should be three or four feet from the wall, with complete ventilation around it; if the tick is filled with straw, it must be fresh; if a hair mattress is used, it, with the bed-linen, should be clean and previously well aired and sunned.

The nurse should be skilled in the care of persons suffering from operations, for frequently success depends upon the skill in the management of the details of nursing after special operations. Cleanliness of the wound, the patient, the clothing, the room, is of the first importance; the diet and the remedies are to be carefully attended to; and the progress of the case, as indicated by the wound, the pulse, and the temperature, is to be noted at sufficiently frequent intervals to make the record of the case complete in the absence of the surgeon.

The Prevention of Hemorrhage.

It is important to make suitable preparation for the prevention of hemorrhage, for excessive bleeding, due to defective measures for its arrest, shows culpable negligence. The preparation must be adapted both to control the circulation in the limb or part during the operation, and to permanently close the divided vessels after the operation.

Elastic Compression.—The most perfect method of preventing loss of blood during the operation is by elastic compression, so applied as to remove the blood from the part and prevent it from re-entering the vessels.

The *elastic bandage* (Fig. 200) is the most serviceable and convenient appliance yet devised to meet all of these important indications. While the

Fig. 200.

Elastic bandage.

Fig. 201.

Elastic bandage applied.

patient is being brought under the anæsthetic apply the bandage, with uniform tightness, from the extremities of the toes or fingers, according to the limb about to be operated upon, to a point above the place of operation; where the bandage ends apply india-rubber tubing, well drawn out, four or five times round the thigh, and connect one end with the other by means of a hook and brass chain; now remove the bandage first applied, commencing with the last turn and descending to the toes

or fingers, leaving the tubing in position. The bandage may be fixed with a strong tape passed under the two or three last turns and tied firmly; then begin with the first turn at the extremity and remove the bandage to the point where it is fastened. The india-rubber tubing so thoroughly compresses all the soft parts, including the arteries, that not a drop of blood can enter the parts below. Even in the most muscular and obese individuals we are able thoroughly to control the supply of blood by this simple process; the limb below the tubing resembles completely that of a corpse, and we may operate as on the dead subject. This method may be adopted in almost all operations on the extremities with more or less complete success. In extirpation of tumors, tying of arteries, and in resections of smaller bones and joints the compressing tubing need not be relaxed until the dressing of the wound is completely finished. When operating upon parts infiltrated with purulent matters do not apply the elastic bandage, as there is danger of forcing the purulent matters upward through the meshes of the cellular tissue, but raise the limb and empty the vessels as completely as possible before applying the tubing.

Arterial Compression.—The control of the circulation may be effected by compression of the artery which supplies the part. As this method, however carefully applied, permits of the loss of the blood contained in the limb, the amount should be diminished, as far as possible, by first elevating the limb and rubbing it toward the heart.

The fingers afford ready and available means of arterial compression when the artery is accessible and lies upon a bone (Fig. 202). If the

FIG. 202.

Digital compression.

thumb is used, it must be laid flat upon the vessel; in either case the pressure must not be relaxed; if the vessel slips from the grasp, it should be instantly compressed again upon the bone by the fingers or

thumbs, but not by grasping the limb; the fingers are best employed in compression of the brachial, the radial, and the ulnar arteries; the thumb in compressing the carotid, the abdominal aorta against the vertebræ, the external iliac against the brim of the pelvis, the femoral against the pubis, or against the femur in the upper part of the thigh.

The key, the ring being so padded as to make a hard mass, is used to compress deep-seated arteries, as the subclavian.

The tourniquet has several modifications (Fig. 203, *a*, *b*, *c*), but the most important difference is in the effect upon the venous circulation; it may compress the limb only at opposite points (*a*) or the entire limb, the pad being placed over the artery (*b*, *c*). The most useful instrument is that in common use (*b*). In its application it is usual

FIG. 203.

Tourniquets.

FIG. 204.

Tourniquet applied.

to put several turns of a roller loosely around the limb at a point where it is applied, terminating with placing the cylinder of the roller over the artery as a compress; the tourniquet should now be applied, but the screw should not be placed over the cylinder, lest the ball roll from the artery when the screw is worked. The screw being placed at one side of the limb (Fig. 204), the strap should be buckled tightly and the screw gradually turned to the necessary tightness. If the point of compression of the artery admits, put the cylinder of the roller between the pad and the strap and apply it directly over the artery.

FIG. 205.

Tenaculum.

FIG. 206.

Artery forceps.

Ligation.—During the operation the hemorrhage should be temporarily controlled by seizing the bleeding points with the catch forceps (Fig. 207), and allowing them to remain in position until the operation has proceeded so far that they must be removed, when antiseptic ligatures should be applied to each.

In applying the ligature to large arteries the coats of the artery

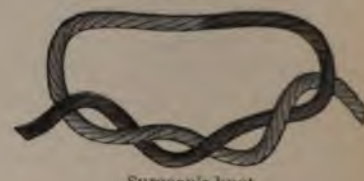
should, as far as possible, be isolated from the surrounding tissues. On applying the ligature make the surgeon's knot (Fig. 208) or the reef knot (Fig. 209).

In some cases the bleeding vessels cannot be isolated, and it becomes

Fig. 207.

Catch-forceps.

Fig. 208.



Surgeon's knot.

Fig. 209.

Reef knot.

necessary to enclose a small area with a ligature (Fig. 210) passed around it with a needle.

Torsion.—The twisting of an artery upon its axis is designed to cause laceration of the internal coats; they then roll into the calibre of the vessel and form a mesh, within which a blood-clot forms and

Fig. 210.

Enclosing tissues.

Fig. 211.

Torsion applied.

becomes organized; the external twisted coat remains as a protection and support. Torsion is a reliable method, especially when applied to small arteries, but is not generally approved for large arteries.

Free torsion is applicable to small arteries, and consists in seizing the extremity of the vessel with firmly-united forceps, drawing it out from its connection, and rotating it several times (Fig. 211).

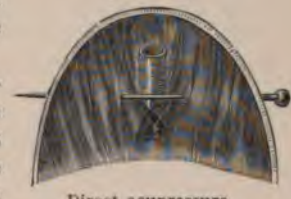
Limited torsion is applied to large arteries, as follows: Seize the extremity of the artery with strong catch-forceps having blunt serrations; draw it well out of its sheath; grasp it firmly with a second forceps about one inch from the end; now rotate the first forceps three or four times or until all resistance ceases.

Acupressure.—Compression of the artery in the wound by means of a needle (Simpson) is only adapted to cases in which the artery cannot be seized or is friable. The instruments required are bayonet-pointed pins varying in length from three to five inches, with glass heads to facilitate their introduction, needles threaded with iron wire, and loops of slender annealed iron wire five or six inches in length. On the cut surface of a flap the ordinary sewing needle answers perfectly well. There are several methods of employing the pins to accomplish compression, but they may be reduced to three (Fig. 213, 1, 2, 3), and will be understood by the illustrations.

Acupressure is seldom resorted to, as with antiseptics it has no advantage over the ligation, except when the artery cannot otherwise be controlled.

Direct compression (Fig. 212) is made by the pin thrust through the flap, passed over the artery, and brought out of the integument of the opposite side in such manner as to firmly compress the mouth of the artery against the muscle upon which it lies.

FIG. 212.



Direct acupressure.

Acupressure by forceps (Allis) is an ingenious method of compressing vessels when there is much oozing from surfaces: the instrument consists of two blades (Figs. 214, 215) under the command of a spring, the lower of which is a needle and designed to transfix bleeding tissues; which done, the grasp of the hand is released, and compression is instantly effected between the blunt blade which lies upon the surface of the bleeding vessels and the needle which lies beneath them.

FIG. 213.

Different modes of applying acupressure.

Cauterization.—The cautery, once the only method of arresting bleeding after operations, is now required only when deep-seated parts are involved, or tissues to which the ligature cannot safely be applied.

The *actual cautery* consists of an iron or steel knob, at the extremity of a long shaft, secured to a handle. The shape of the extremity may be round or pear-shaped, or flat like a button; each form is adapted to special conditions requiring its use. It may be heated in the flame of a spirit lamp; when employed to arrest hemorrhage its temperature should be at a dull red heat.

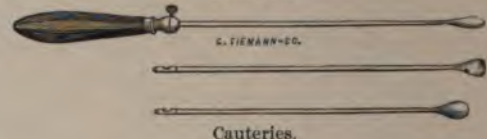
Fig. 214.

Fig. 215.

Acupressure forceps.

The *thermo-cautery* (Fig. 217) is an instrument by which a high degree of heat of the cautery may almost instantly be obtained, and may be maintained for any length of time without the slightest inconvenience.

Fig. 216.



Cauteries.

By adapting a blade to it dissections may be made, and with the wire écraseur tumors may be removed in a bloodless manner.

Ligation of Arteries.—The application of a ligature to an artery can now scarcely be considered a serious operation, for when the antiseptic

Fig. 217.

Paquelin's cautery.

method is pursued suppuration does not occur, and if the proper kind of ligature is used division of the artery does not follow, and hence there is no danger of secondary hemorrhage. It is now established that when an artery is closed by an aseptic ligature it is not necessary to divide the internal coat, but only to press its opposing surfaces together temporarily, to secure permanent obliteration of its canal. In this process the intima becomes covered with granulations; these unite and form a firm union;

also new tissue forms around the ligature, like a ring of callus, strengthening the point of ligation; meantime the ligature undergoes absorption and the cure is complete. By the antiseptic operation the artery is strengthened at the seat of ligature, and there can be no danger of hemorrhage. It should, however, be borne in mind that to secure the best results the ligature must be of an absorbable nature; for ligatures which permanently resist absorption destroy the continuity of the vessel, and, instead of adding strength to the perivascular cicatrix, weaken the vessel-walls at the seat of ligation.

The *instruments* required are a scalpel, forceps, aneurism needle, ligature, director, and retractors or spatulas. The common scalpel is best adapted for the dissection, and the broad extremity of the handle can be used to advantage in separating layers of fascia and parts where the cutting edge is not desirable; the dissecting forceps should have accurately fitting teeth, and not liable to open at the extremity when firmly closed; a pair of small forceps may also be required. The aneurism needle is a curved blunt instrument, with an eye near the extremity and firmly fixed in a handle (Fig. 218). When used, the extremity is gently insinuated under the vessel, and as it appears upon the opposite side the loop of the ligature is seized with the forceps or a hook, and, one end being drawn through, it is held as the instrument is withdrawn carrying the other end, and thus leaving the ligature under the vessel. A needle well adapted to those cases where the artery lies deeply consists of the handle and hook (Fig. 220) and the blunt needle with two eyes (Fig. 219); the needle is fitted to the shaft (Fig. 220) by a screw; when used, the ligature is inserted into the second eye; the needle is then passed under the artery, and as the extremity emerges upon the opposite side the hook is inserted into the first eye, and the needle is thus held until the handle is unscrewed, when it is drawn through with the ligature. It is sometimes necessary to include other tissues with the artery, when the sharp-pointed needle (Fig. 219) should be used. The director is used in the dissection to raise the fascia before its division; it is sometimes passed under the artery as a guide to the needle. Two retractors are often required, with which assistants separate the sides of the wound and expose the deep-seated parts; pieces of flexible metal or wood may be used.

FIG. 218.

Aneurism needle.

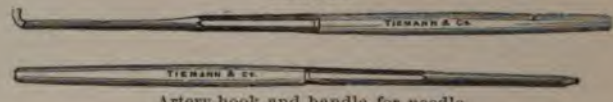
FIG. 219.

Needles for deep ligations.

The *aseptic catgut or silkworm-gut ligature* more effectually meets the indications present than other kinds. When so applied as not to sever the tunics of the ligated vessel it is gradually displaced by organized tissue which increases the resisting capacity of the vessel. It is stated that the most careful microscopical examinations have shown that catgut increases to a considerable extent the resisting capacity of an artery in forming firm connective-tissue connections with the vessel. It follows that catgut ligature should be preferred, and that it is only necessary to tie with sufficient force to approximate the inner surfaces of the intima with a

view to ensure effective provisional obliteration, when cicatrization will follow.

FIG. 220.



Artery-hook and handle for needle.

The *operation* is as follows: Determine the precise location of the artery—(1) by its pulsation; (2) by reference to anatomical points in the vicinity. To render the former distinct, the limb should be placed in a position favorable to arterial circulation; to render muscles and tendons most distinct, the limb should be forcibly extended at the commencement of the operation. When the dissection has proceeded so far as to reach the vicinity of the artery, the operator is aided in detecting its position by flexing the limb, so as to relax the muscles and tissues. Before the first incision is made guard against wounding superficial veins. Their position is readily defined by compressing the parts above the point of the proposed operation. When the first incision is about to be made the skin should be rendered tense by the thumb and forefinger of the left hand applied, one on either side of vessel, or by the fingers applied at the extremity of the proposed incision parallel to its course: if the first method is chosen, care must be taken not to make more traction on one side than on the other. The second method answers where the skin is naturally tense and but slight traction is necessary; make the incision directly over and parallel to the artery, through the skin only if the artery is superficial, but also through the cellular tissues if it is deep, its length varying with the depth of the vessel and the adipose tissue. The incision is sometimes made in the direction of the fibres of the muscle covering the artery, as where the great pectoral overlies the axillary; at other times it should be curved, so as to raise a flap.

FIG. 221.

Opening the sheath.

The length of the incision cannot be prescribed, but it should always be ample. Pinch up the fascia carefully with the forceps (Fig. 221); nick it with the scalpel applied horizontally; incise freely on a director introduced beneath. In dissecting among muscular structures enter the muscular interstices and do not wound the substance. These intermuscular spaces are marked by deposits of fat, especially toward the terminal extremity of the muscles, and hence we should commence the separation of muscles as nearly as possible at their terminal extremity. If there is doubt as to the line of separation, a puncture will disclose adipose or

muscular tissue, according to the nature of the underlying structure. If the dissection is made through the body of the muscle, the fibres separate more readily in an inverse direction—namely, from their origin to their attachments. The muscles may be separated with the handle of the scalpel or the finger-nail.

The larger arteries have firm sheaths, which require to be opened by dissection; the smaller vessels have but slight investments, and are

FIG. 222.

Passing the needle: first stage.

FIG. 223.

Passing the needle: second stage.

readily exposed with the point of a director or the aneurism needle. The sheath is opened by pinching up a small portion with the forceps and nicking it slightly with the scalpel; into the opening thus made introduce the point of the needle (Fig. 222); by slight movements of its point, first upon one side and then upon the other, separate the sheath completely around the vessel to an extent sufficient to allow simply the passage of the ligature; as the extremity of the instrument emerges on the opposite side, with the finger of the left hand or the thumb and forefinger pressed together steady its point as it penetrates the last portion of the sheath. If the artery is small and very superficial, a director may be passed under and along its groove, a blunt needle carrying the ligature. If more deeply situated, the common aneurism needle (Fig. 218) or the double-eye needle (Fig. 219), should be used. The point of the needle, gently moved laterally, aids materially in separating the artery from the sheath (Fig. 223). The needle should be passed from the veins; no force should be used, lest the instrument penetrate the coats of the artery.

The ligature should be placed at a right angle with the long axis of a vessel, and the reef-knot (Fig. 209) tied unless there are special reasons for adopting the surgeon's knot (Fig. 208). The first knot is tightened around the vessels firmly, on either side of the ligature, near the artery, with the index fingers carried to the bottom of the wound (Fig. 224). The degree of constriction varies with the size of the arteries, but it

need not be so great as to rupture the internal coats. In tying the second knot care must be taken not to tighten the thread firmly until traction is made on a plane with the first knot, with the fingers again carried down to the vessel. The two ends of the ligature must be cut not too near the knot.

FIG. 224.

Tying the knot.

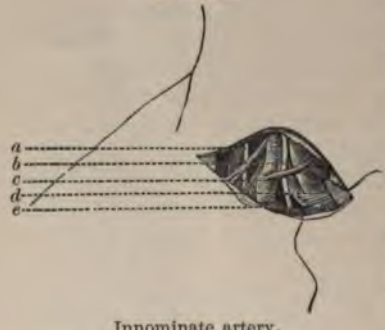
The *dressing of the wound* should be strictly antiseptic for the purpose of securing immediate union. A catgut drain should be placed in the lowest angle. The deeper structures may first be stitched with the continuous catgut suture; then, if the wound is large, two or three deep sutures of relaxation may be inserted. Close the cutaneous wound with the continuous or interrupted suture. Complete the dressing by antiseptically cleaning the external surface, dusting it with iodoform, and applying the iodoform gauze or a bandage of bichloride gauze.

ARTERIES OF THE THORAX, NECK, AND HEAD.

The *innominate* artery is in relation on the right with the pleura, right vena innominata, and right pneumogastric nerve; behind, with the trachea; on the left, with the left carotid; in front, above, with the sternum and the origin of the sterno-hyoid and thyroid; below, with the inferior thyroid vein and left vena innominata.

Operation.—Place the patient on the back, with the shoulders slightly raised, the right arm drawn downward, and face turned to the opposite side; make an incision three inches in length just above the clavicle) terminating over the trachea, and, if required, a second of the same length from this point along the inner border of the sterno-mastoid; divide the sternal and part of the clavicular portion of the sterno-mastoid (Fig. 225, *e*) on a director and turn outward; divide the sterno-hyoid and thyroid in the same manner; draw them inward, exposing the sheath of the carotid, par vagum, and internal jugular vein; now separate the par vagum, *b*, from the carotid; draw the vein, *c*, to the outside, and the artery toward the trachea, and expose the subclavian; the innominate artery, *d*, is now uncovered; pass the needle from below upward and inward; care is necessary to avoid wounding the pleura behind.

FIG. 225.



Innominate artery.

The *subclavian and common carotid arteries* (Fig. 226) may be ligated by the following operation: Place the patient in the position for ligature of the innominate; make an incision three inches in length through the

integuments, along the space separating the clavicular and sternal attachments of the sterno-cleido-mastoid muscle; this interval is marked by a depression above the clavicle at the articulation of the clavicle and sternum; flex the head; slightly separate the internal portion of the muscle, *a*, from the external, *b*; divide the sterno-hyoid and thyroid on the director. The innominate, *h*; the common carotid, *e*; the pneumogastric, *d*, and its branch, the recurrent laryngeal; the origin of the subclavian, *g*, and its branches, the vertebral, *c*, and inferior thyroid, are now under control.

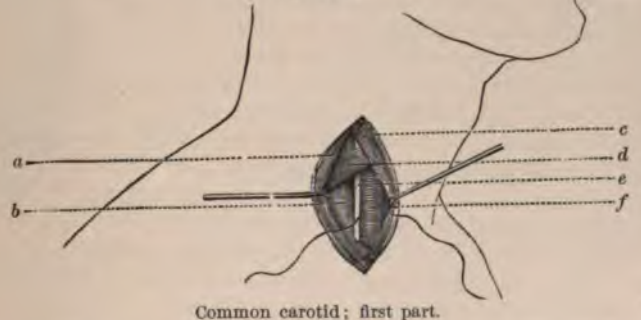
FIG. 226.

Subclavian and common carotid arteries.

The *common carotid arteries* extend on the right side from the innominate, and on the left from the highest point of the arch of the aorta, to the upper border of the thyroid cartilage; the direction is obliquely from before backward, and from within outward, along the external side of the trachea and larynx, in a line drawn from the sternal end of the clavicle below to a point midway between the mastoid process and angle of the jaw above. The sheath is derived from the deep fascia, and contains the internal jugular vein and the pneumogastric nerve, the vein being external and the nerve between.

(*a*) At the base of the neck the artery is deeply seated. The carotid tubercle is a guide to the position of the artery; this tubercle is the anterior projection of the transverse process of the sixth cervical vertebra, which is two inches above the clavicle, and is a precise guide to the artery when the neck is straight; it corresponds in front and a little inside to the artery (Fig. 227). The patient being in the recumbent position,

FIG. 227.



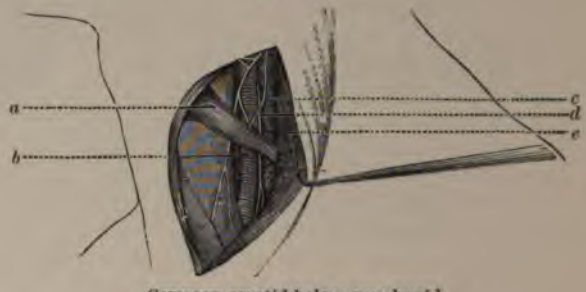
Common carotid; first part.

the head extended and inclined to the opposite side, recognize the interval between the two attachments of the sterno-mastoid muscle, and make an incision from the clavicle, two and a half inches, obliquely along this interspace; divide the skin, platysma, and deep fascia; draw the internal portion of the muscle, *c*, inward, and the external, *a*, outward, by means of spatulas; this exposes the internal jugular vein, *b*, the pneumo-

gastric nerve, *e*, lying between the vein, *b*, and the artery, *f*, and the omo-hyoid muscle, *d*, crossing the upper part of the wound; open the sheath and pass the needle from without inward, carefully avoiding the internal jugular vein and par vagum; a finger pressed upon the vein at the upper part of the wound will cause it to collapse.

(*b*) Below the omo-hyoid the artery is much more accessible (Fig. 228). Place the patient on the back, with the head thrown back; make

FIG. 228.



Common carotid below omo-hyoid.

an incision three inches in length along the inner border of the sterno-mastoid muscle, in the line above given, terminating at the top of the sternum; successively divide the skin, superficial fascia, platysma, and deep fascia, and expose the inner border of the sterno-mastoid, *e*; carefully avoid the sterno-mastoid artery and middle thyroid vein; throw the head forward and draw the sterno-mastoid muscle outward and the sterno-hyoid and thyroid muscles inward; expose the anterior belly of the omo-hyoid muscle, *a*, which should be drawn upward; divide the deep fascia; expose the sheath of the vessel; open it directly over the artery, avoiding carefully the descendens noni, which runs along the tracheal side; press the pneumogastric nerve, *d*, and internal jugular vein, *c*, outward, and pass the needle from without inward, carefully isolating the vessel from the inferior thyroid artery and recurrent laryngeal nerve which lies behind it.

FIG. 229.

Right common carotid artery at the seat of ligature: *pl*, platysma; *s. m*, sterno-mastoid, drawn to one side; *o. h*, omo-hyoid, drawn downward and inward; *s. h*, sterno-hyoid; *a*, the artery; *v*, internal jugular vein; *d. n. n*, descendens noni nerve. The pneumogastric is not seen, as it lies behind the vessels.

(*c*) Above the omo-hyoid the artery is still more superficial, being covered only by the skin, the two fasciæ, platysma, and the border of the sterno-mastoid; it is in relation internally with the larynx and pharynx, and externally with the pneumogastric nerve and internal jugular vein (Fig. 229). Place the patient on the back, the shoulders raised and the head turned to the opposite side; make an incision from a little below the angle of the jaw, in the line given, along the internal border of the sterno-mastoid, three inches in length; divide the integuments, superficial fascia, and platysma; raise the deep fascia carefully on a director; avoid the small

underlying veins ; flex the head to relax the muscles, and draw the wound apart by spatulæ ; avoid the descendens noni nerve and superior thyroid arteries, and open the sheath over the artery ; if the internal jugular vein swell up into the wound, compress it in the upper and lower parts of the wound, and draw it outward ; pass the ligature from without inward, the point of the needle being kept close upon the artery, to avoid wounding the vein or including the pneumogastric nerve (Fig. 230).

The *external and internal carotids* arise from the common trunk at the upper border of the thyroid cartilage, the external being more

FIG. 230.

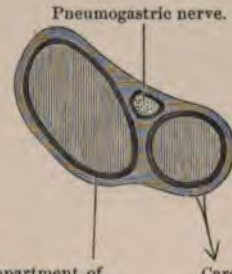

Pneumogastric nerve.
Jugular vein: venous compartment of sheath, the part to be avoided.
Carotid artery, showing arterial compartment of sheath. An arrow indicates the part to be opened.

Diagram of the carotid sheath (Sir W. MacCormac).

superficial than the internal at their origins. Make an incision along the inner margin of the sterno-mastoid, three inches in length, from the angle of the jaw to the cricoid cartilage, through the skin, platysma, superficial and deep fascia ; the internal margin of the sterno-mastoid now appears ; cautiously separate the cellular tissue, and, the wound being drawn apart, the external carotid artery is exposed ; draw the digastric muscle and hypoglossal nerve upward and the internal jugular outward ; both arteries may now be ligated, or either artery separately.

The *external carotid artery* ascends from its origin at first slightly forward, then backward, to the space between the condyle of the lower jaw and the meatus auditorius ; above the digastric the artery lies more deeply and is crossed by the stylo-hyoid muscle. Make an incision from near the angle of the jaw to the middle of the thyroid cartilage, along the inner margin of the sterno-mastoid, about three inches ; divide the skin, platysma, and fascia ; seek with the finger the tip of the great cornu of the hyoid bone.

The *superior thyroid artery* arises from the external carotid, just below the greater cornu of the hyoid bone, and passes inward to the thyroid gland in a tortuous course. Place the head in an extended position ; make an incision an inch and a half along the internal border of the sterno-mastoid, the centre of which corresponds to the great cornu of the thyroid cartilage ; incise the skin and platysma ; draw the sterno-mastoid outward and expose the omo-hyoid muscle, internal jugular vein, and primitive carotid artery ; the artery lies between these vessels and the lobe of the thyroid body ; pass the needle from above downward with the point inclined to the thyroid body.

The *lingual artery* (Fig. 232), the second branch of the external caro-

tid, arises just above the superior thyroid, ascends to the great cornu of the hyoid bone, runs parallel with it and passes inward on the middle constrictor and genio-hyoglossus to the outer edge of the hyoglossus muscle; it then passes upward and inward beneath the digastric, stylo-hyoid, and hyoglossus muscles to the base of the tongue. The artery passes through three regions: (1) external to the hyoglossus muscle, (2) beneath the muscle, (3) from its inner margin to the tip of the tongue; the second portion is selected for ligation. Turn the head to the opposite side; make an oblique incision an inch and a half in length, a little above the body of the hyoid bone, and parallel with it, near the median line, and curved backward, outward, and downward, parallel with the superior border of the great cornu of the thyroid cartilage (Fig. 231);

FIG. 231.

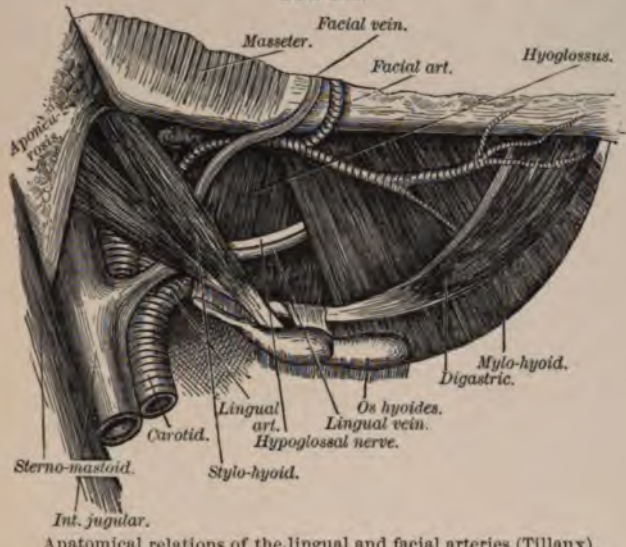
Lines of incision for ligature of the first part of the axillary artery, the third part of the subclavian, the common carotid, and the lingual.

divide the superficial parts, and with the finger recognize the direction of the great cornu; divide upon it the aponeurosis which covers the deep parts; this exposes the digastric muscle, the submaxillary gland, hypoglossal nerve, and stylo-hyoid muscle; now isolate the great cornu of the hyoid bone, and the fibres of the hyoglossus muscle, which are attached at this point, come into view; divide this muscle at the superior border of the great cornu; draw it upward and backward, and the artery is found behind it; the needle should pass from above downward.

The *facial artery* (Fig. 232) arises a little above the lingual, is first directed obliquely forward and upward beneath the base of the maxillary bone, where it changes its direction and passes upward over the base of the lower maxilla in front of the masseter muscle. It consists of a cervical and facial portion: the first is comparatively superficial, being covered only by the platysma and fascia, is crossed by the digastric and stylo-hyoid muscles, and then enters the submaxillary gland. Emerging from the gland, the second part turns over the jaw, covered

by the platysma and fascia, and ascends to the inner canthus of the eye. In the first part make an incision similar to that for exposing the lingual artery, but nearer the base of the jaw; incise the skin and tissues over

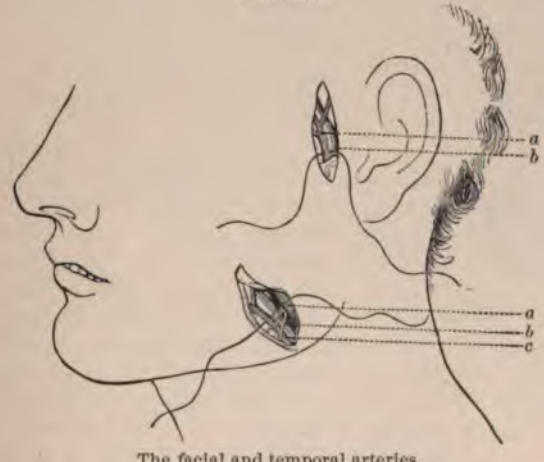
FIG. 232.



Anatomical relations of the lingual and facial arteries (Tillaux).

the submaxillary gland; draw the gland upward, and the artery will also be raised, when it can be easily separated from the vein and ligated. In the second part (Fig. 233) recognize at the junction of the posterior third with the anterior two-thirds of the body of the bone the pulsation

FIG. 233.



The facial and temporal arteries.

of the artery; make an incision an inch in length along the course of the vessel, as already given, through the skin, fascia, and platysma; the wound being separated and the fibrous tissue divided, the artery, *c*, is

exposed, and the vein, *b*, and masseter muscle, *a*, are drawn outward and the needle passed.

The *temporal artery* (Fig. 233) runs upward toward the temporal region from its origin at the condyle of the jaw, in front of the concha; two inches above the zygoma it divides into the anterior and posterior branches. Recognizing the position of the artery by its pulsation, at a point above the zygomatic arch and in front of the ear make an incision through the skin an inch in length; divide the dense cellular tissue on a director, and the artery, *a*, will be exposed; pass the needle from behind forward to avoid the temporal vein, *b*, and the auriculo-temporal nerve.

The *middle meningeal artery* is the largest branch of the internal maxillary and the largest artery which supplies the dura mater. It ascends under the external pterygoid muscle, and enters the skull through the spinous foramen of the sphenoid bone; within the skull it passes beneath the dura mater to the middle fossa, where it divides into two terminal branches; the anterior, the larger, passes upward on the great wing of the sphenoid in a deep groove in the anterior inferior angle of the parietal bone, where it divides. This division may be ligated for intracranial hemorrhage. The artery is most accessible where it crosses the anterior inferior angle of the parietal bone. Determine the position of the artery by the intersection of a horizontal line drawn two inches above and parallel to the zygoma, with a vertical one an inch behind the posterior superior border of the malar bone; make a crucial incision through the skin, divide the temporal muscle, and expose the skull; the bone is unequally thick in this region, and care must be taken in using the trephine; the circle of bone being removed, the bleeding vessel may be ligated or pressure may be employed to arrest hemorrhage.

The *occipital artery* arises from the posterior part of the external carotid, opposite or a little above the facial, ascends beneath the posterior belly of the digastric muscle to the space between the transverse process of the atlas and the mastoid process, and is distributed to the occipital region.

FIG. 234.

Occipital artery.

At its origin the artery is covered by the stylo-hyoid and digastric muscles, and the hypoglossal nerve winds around it from behind forward. Make an incision along the inner border of the sterno-mastoid muscle, two inches in length, at the angle formed by this muscle and the digastric; the deep fascia being carefully divided, expose and isolate the artery, the nerve being protected.

Behind the mastoid process (Fig. 234) the artery passes upward in a tortuous direction, and divides into branches upon the occiput; it is covered by the sterno-mastoid and splenius muscles. Make an incision, one inch long, half an inch behind, and a little

beneath the mastoid process, obliquely upward and backward; divide the skin and aponeurosis of the sterno-mastoid muscle, *c*, as also the splenius muscle, through the whole length of the wound; the pulsations of the artery, *a*, are recognized by the finger a little above the oblique muscle, *b*, and it is isolated from its veins.

The *posterior auricular artery* arises in the parotid gland nearly opposite the apex of the mastoid process; it ascends to the interval between the mastoid process and external auditory meatus, where it divides. Make a vertical incision midway between the two points above given; the pulsations of the artery will prove the immediate guide for its ligation.

The *internal carotid artery* continues directly upward from the termination of the common carotid, opposite the upper border of the thyroid cartilage to the carotid foramen of the temporal bone; at first it is covered only by the sterno-mastoid muscle, platysma myoides, and fascia; it lies to the outer side of the external carotid. Make the same incision as for the common trunk, its centre being one-half to three-quarters of an inch above the upper border of the thyroid cartilage; veins will be met with which must be avoided or tied; the descendens noni nerve runs along the artery, and the hypoglossal crosses it about one inch from its bifurcation. First find the external carotid, and draw it inward. Pass the needle from the outer side, carefully avoiding the jugular vein and pneumogastric nerve externally, the hypoglossal nerve superficially, and the external carotid internally.

The *internal mammary artery* arises from the subclavian on its lower and anterior part, opposite the thyroid axis and close to the anterior margin of the scalenus anticus; it runs directly downward and slightly inward behind the clavicle on the inner surface of the costal cartilages near the sternum. The internal jugular and subclavian veins and the phrenic nerve cross the upper part; in the chest it at first lies on the costal cartilages and intercostal muscles, covered by the pleura behind; but lower it is covered also by the triangularis sterni muscle. It may be tied in the second, third, or fourth intercostal spaces. Make an incision along the upper edge of the costal cartilage, commencing at the sternum, in either space, slightly upward and outward, an inch and a half in length; divide the skin, cellular tissue, pectoralis major muscle, fascia, and intercostal muscle successively; a thin layer of cellular tissue is exposed, which conceals the artery; pass the needle cautiously from within outward.

The *vertebral artery* (Fig. 235) arises from the upper and back part of the subclavian artery in the first part of its course, about one-third of an inch internal to the inner border of the scalenus anticus muscle, and passes directly along the spinal column to the foramen in the transverse process of the sixth cervical vertebra, and then ascends through the series of foramina of the transverse processes to the cavity of the cranium. Before entering the vertebral canal the artery passes behind the internal jugular vein and inferior thyroid artery to the spine, where it lies between the scalenus anticus and longus colli, and in a line drawn from the posterior part of the mastoid process to the junction of the internal fourth with the external three-fourths of the clavicle. Place the patient on the back, the shoulder depressed, and the head turned to

the opposite side; make an incision three inches in length from the clavicle along the outer border of the sterno-mastoid muscle; divide the the skin, and cellular tissue; bring into view the common sheath of the

FIG. 235.

Anatomy of the vertebral and inferior thyroid arteries (from Treves): *A*, thyroid gland; *B*, trachea; *C*, clavicle; *D*, sterno-thyroid; *E*, scalenus medius; *F*, longus colli, with sympathetic nerve upon it; *G*, scalenus anticus (cut); *H*, subclavius; *I*, transverse process of the sixth cervical vertebra; *J*, brachial plexus; *a*, left innominate vein, receiving internal jugular; *b*, jugular vein, entering subclavian vein; *c*, common carotid artery, with vagus nerve to its inner side; *d*, subclavian artery crossed by nerve to subclavius; *e*, vertebral artery and vein; *f*, inferior thyroid artery.

carotid, the internal jugular, and the pneumogastric nerve; separate with the finger the cellular connection of the sheath with the sterno-thyroid muscle, and finally with the longus colli; the head is now raised, though still turned to the opposite side, and the sides of the wound forcibly separated; divide the cellular tissue at the bottom, and expose an aponeurosis which passes from the scalenus anticus to the longus colli and the anterior part of the transverse process of the sixth cervical vertebra, the carotid tubercle; then open the aponeurosis an inch below this point at the external border of the longus colli muscle; the artery is exposed very deeply situated.

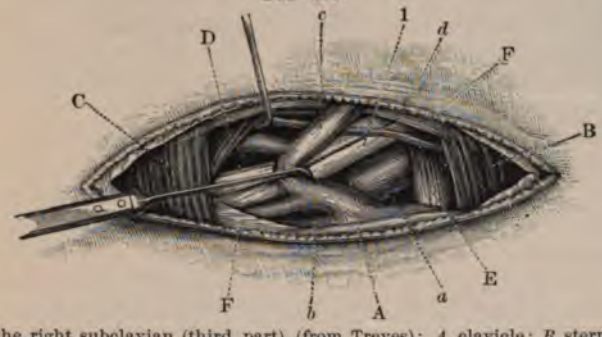
The *inferior thyroid artery* (Fig. 235) is a branch of the thyroid axis; it ascends the neck obliquely, passing behind the internal jugular, the pneumogastric nerve, the carotid artery, and omo-hyoid muscle to the thyroid body. On the left side it lies on the œsophagus, and the thoracic duct is at first posterior, and afterward arches over it in front of the artery to the left subclavian vein; near the gland the recurrent laryngeal nerve often passes between its terminal branches. Make the same incision as for the ligature of the common carotid (Fig. 227). When its sheath is reached, draw it outward; the artery crosses obliquely inward opposite this point; when the vessel is fully exposed apply the ligature as near the carotid as you can to avoid the recurrent laryngeal nerve.

ARTERIES OF THE UPPER LIMB.

The *subclavian artery* arises from the innominate on the right side, and from the arch of the aorta on the left; it extends in a curved direc-

tion from its origin to the lower border of the first rib. It may be ligated in three places—viz. inside, between, and outside the scaleni muscles; the latter location is always to be preferred, and will be described. Outside of the scaleni muscles (Fig. 236) the artery passes

FIG 236.



Ligature of the right subclavian (third part) (from Treves): *A*, clavicle; *B*, sterno-mastoid; *C*, trapezius; *D*, omo-hyoid; *E*, anterior scalena; *F*, cervical fascia; *a*, subclavian artery; *b*, subclavian vein; *c*, ext. jugular vein; *d*, transverse cervical artery; 1, brachial plexus.

downward and outward, lying in a groove on the first rib. It first passes through the supra-clavicular triangle, and is then covered only by the deep fascia, the platysma, and skin; lower in its course it is covered by the clavicle and subclavian muscle; the subclavian vein lies lower and in front of the artery, separated from it by the insertion of the scalenus anticus muscle; the external jugular vein crosses in front of the artery; the brachial plexus of nerves lies above and behind the artery. The depth of the artery may vary from one to three inches, according to the depth of fat. Search for the artery in the supra-clavicular triangle, which is bounded externally by the omo-hyoid muscle, internally by the scalenus anticus, and below by the first rib; place the patient on his back, the shoulders depressed, and the head turned to the opposite side; the skin over the parts being drawn down upon the clavicle, make an incision along the bone from the anterior border of the trapezius to the posterior border of the sterno-mastoid; divide the platysma and superficial fascia, care being taken to draw the external jugular outward, or, if cut, to tie the ends; with the director and finger separate the cellular and fatty tissue, and draw the omo-hyoid muscle aside; divide the deep fascia, and, the border of the scalenus being defined, pass the finger along its margin down to the first rib; recognize the tubercle for the attachment of that muscle, just external to which the artery will be felt pulsating; separate the attachments of the artery with the finger-nail, and gently insinuate the aneurism needle beneath it, from before backward, and slightly from within outward, avoiding the vein; guide the point of the needle by the end of the finger, and prevent it, when it emerges upon the opposite side, from engaging a branch of the brachial plexus. It must be remembered that the sterno-mastoid may have an unusually extended insertion upon the clavicle, as also the trapezius, in which case the incision must involve the clavicular attachments of the former; the external jugular, supra-scapular, and transverse cervical veins form a plexus immediately over

the artery; the external jugular may run so near to the sterno-mastoid as to be involved in the incision, unless it is carefully isolated and drawn to the outer or inner side; the transverse cervical and supra-scapular arteries may be met with in this dissection, and if wounded should be immediately ligated; the tubercle of the rib is sometimes not well defined, in which case the tense edge and attachment of the scalenus to the rib are the guides to the artery, which is found just posterior to its insertion; there is a liability to include the lowest cord of the brachial plexus, or even to mistake it for the artery; the former is round and tense, the latter is flattened.

The *axillary artery* extends from the lower border of the first rib to the lower margin of the tendon of the latissimus dorsi or the inferior boundary of the axilla, in a line dividing the anterior and middle third of the axilla. It may be ligated in two places. (*a*) Below the clavicle, in its upper part, the axillary artery is covered successively by the insertion of the pectoralis minor; higher up by the pectoralis major muscle, from which it is separated by a layer of adipose tissue containing numerous small veins and arteries; and finally by the fasciæ and the skin (Fig. 237). The supra-scapular artery crosses the base of the neck just above the clavicle; the axillary vein, in front and to the inner side of the artery, is not in immediate contact with it; the cephalic vein passes upward in the interspace between the deltoid and pectoralis major muscles, crosses the axillary artery above the pectoralis minor, and empties into the axillary vein; the nerves of the brachial plexus lie behind and above; a thoracic branch often crosses the artery, sometimes in front and sometimes behind it. Place the patient on his back with his shoulders slightly raised, the elbow a little separated from the body, and the head inclined to the opposite side; make an incision, three inches in length, three-quarters of an inch below the clavicle, and commencing about two inches outside of the sterno-clavicular articulation, through the skin, platysma, and subcutaneous cellular tissue; separate the fibres of the pectoralis major gradually until the posterior investment of this muscle, like an aponeurosis, appears; now depress the shoulder and tear this fascia with the point of the director; press downward and outward with the finger the upper border of the pectoralis minor, when the axillary vein is brought to view; draw this gently forward with a blunt hook, and behind it the artery is found, with the nerves of the brachial plexus still farther behind and above; pass the needle from within outward.

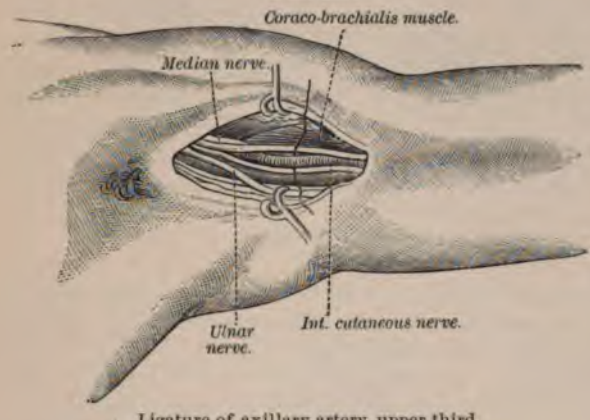
FIG. 237.

The first part of the right axillary artery: *p. m. a*, pectoralis major, the fibres separated in the inner half of the wound and divided in the outer; *p. m. i*, pectoralis minor; *a. t*, acromio-thoracic artery and vein; *v*, axillary vein; *a*, axillary artery; *n*, brachial plexus.

(*b*) Below the pectoralis minor, in its lower third, the artery is superficial, covered only by the integuments and deep fascia. The coraco-brachialis muscle is in contact with the artery, and may be found at its internal and posterior border; the branches of the brachial plexus of

nerves surround the artery; the musculo-cutaneous lies along the outer side; the two roots of the median meet in front at the lower border of the pectoralis minor; the nerve then lies in front and to the outer side of the artery; the internal cutaneous lies in front and to its inner side; the ulnar and radial are still farther within and behind; the axillary vein is in front of the artery and nerves, which it partly conceals (Fig. 238). Place the patient on the back, the arm rotated outward; stand on the outside if it is the right arm, and on the inner side if it is the left; recognizing the inner border of the coraco-brachialis muscle and the

FIG. 238.



Ligature of axillary artery, upper third.

pulsations, make an incision two or three inches in length in the line indicated, dividing only the skin; incise the fascia on a director; with the end of the director push the axillary vein backward, then the brachial plexus; the median nerve is now recognized, and, being brought forward, while the internal cutaneous and ulnar are pushed backward, the artery is exposed; separate the artery carefully from the vein, which is pushed backward, and the nerves which surround it, and pass the needle from behind forward.

The *brachial artery* extends from the lower margin of the axilla to an inch below the bend of the elbow, in a line drawn from the junction of the anterior with the middle third of the axilla to the middle of the bend of the elbow.

(*a*) In the upper third, the arm being extended as before, make an incision two and a half inches in length along the inner border of the coraco-brachialis; the artery is readily exposed, lying between and behind the median and ulnar nerves, the former to the outside and the latter to the inside.

(*b*) In the middle of the arm the brachial descends on the inner side, first of the coraco-brachialis, and afterward of the biceps. It is covered by the fascia and integuments, and overlapped slightly by the biceps; its sheath contains the two venæ comites; the internal cutaneous nerve lies superficial to it; the median is superficial to it above, and rather to its outer side; about the middle of the arm it crosses the artery, and

inferiorly it is to its ulnar side; the ulnar nerve is internal to the artery, and at some distance from it inferiorly; the spiral nerve is posterior, and separates it above from the triceps (Fig. 239). The arm extended at right angles to the body and held supine, the course of the artery may be recognized by its pulsation; by the internal margin of the biceps and

FIG. 239.

Brachial artery in the middle of the arm.

coraco-brachialis; by the median nerve, to the inner side of which it lies; or by the line above given. Make an incision two or three inches in length along the inner border of the biceps down to the fascia, which incise on a director; the position of the median nerve is detected in the wound; push it aside with the biceps; the artery is found immediately behind and inside, accompanied by its venæ comites. The arm is now flexed, the vessel isolated, and the ligature passed from without inward. If the incision is made a little too far back, the ulnar nerve is exposed, and is liable to be mistaken for the median; and this error may be confirmed by the presence of the vein, occupying the same relative position

FIG. 240.

Brachial artery at the elbow.

as the brachial to the median, which may be mistaken for the artery, and then the inferior profunda will be tied for the brachial.

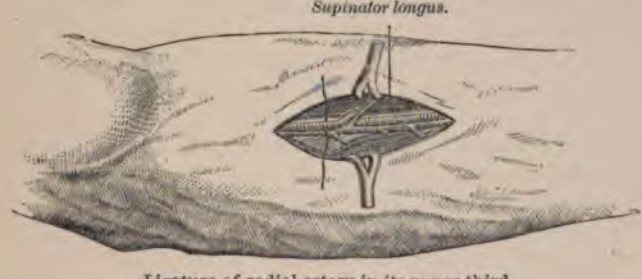
(*c*) At the elbow the brachial artery lies in the centre of a triangular space formed by the supinator longus externally and the pronator radii teres internally. It rests on the brachialis anticus; the median nerve

lies to the inner side half an inch; the tendon of the biceps lies on the outer side; its coverings are the skin, superficial fascia, and the median basilic vein, which is separated by the bicipital fascia.

The arm extended and held in a supine position (Fig. 240), make an oblique incision, two inches and a half in length, along the internal edge of the tendon of the biceps, within the median basilic vein, dividing only the skin; push aside the vein and divide the aponeurosis, which is the deep fascia, on a director; the tendon of the biceps is now seen, and on its inside the artery with its two veins, and still farther inward the median nerve; slightly flex the forearm, and pass the needle from within outward, carefully avoiding the veins.

The *radial artery*, though the smaller branch of the brachial, lies in the direct course of the latter like a continuation; its course is marked by a line drawn from the centre of the elbow to the inner side of the styloid process of the radius; is superficial throughout nearly its entire course; the needle may be passed in either direction. (*a*) In its upper third the artery lies between the supinator longus and the pronator radii teres; the radial nerve lies immediately on its external side (Fig. 241).

FIG. 241.



Ligature of radial artery in its upper third.

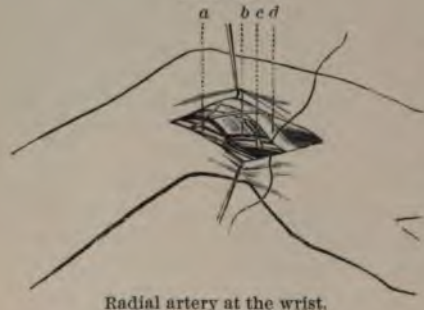
The limb being extended supine, the superficial veins made prominent by pressure of the thumb above, make an incision two or three inches in length on the internal border of the supinator longus, if recognized by the depression, or on a line drawn from the middle of the bend of the elbow to the inner side of the styloid process of the radius, dividing the skin and superficial fascia; divide the deep fascia on a director; flex the arm slightly to relax the muscles; the supinator longus being drawn aside, the sheath of the artery is exposed; pass the needle from without inward.

(*b*) In its lower third the artery is superficial, lying between the tendons of the supinator longus and the flexor carpi radialis; it is accompanied by venæ comites and by the radial nerve, which lies external; its pulsation is easily detected (Fig. 244). The arm held supine, the hand forcibly extended to make prominent the flexors, and the operator standing on the external side of the limb, make a light incision two inches in length, from half an inch above the articulation of the radius, on the external border of the flexor carpi radialis, or on a line joining the external with the three internal fourths of the arm; the deep fascia is raised on a director, exposing the artery with its two veins, and the

nerve, external and posterior; the needle may be passed in either direction.

(*c*) On the dorsum of the wrist (Fig. 242) the artery passes in the groove between the upper extremities of the first metacarpal bones; a fibrous band separates it from the tendons of the thumb. It may be tied just as it is about to form the palmar arch, or as it passes under the extensor muscle of the thumb, between the extensor primi internodii and the extensor secundi internodii pollicis, a little below and posterior to the extremity of the styloid process of the radius. Make an incision an inch in length along the outer borders of the extensor secundi and metacarpi pollicis, at the angles formed by the two first metacarpal bones, care being taken not to wound the superficial veins; the artery is readily exposed. At the higher point place the hand between pronation and supination, the thumb strongly abducted so as to render prominent the extensors, and make an incision an inch in length between the tendons of the two extensors, commencing at the lower extremity of the radius and in the line of the axis of the first metacarpal bone; makes these incisions lightly, to avoid the superficial vein of the thumb; draw the extensor ossis metacarpi pollicis, *a*, inward, and the extensor secundi internodii pollicis, *d*, outward; expose the artery, *c*, and its accompanying veins, *b*.

FIG. 242.



Radial artery at the wrist.

The *ulnar artery* is indicated by a line drawn from the internal tuberosity of the os brachii to the external side of the pisiform bone. (*a*) In its upper third the ulnar artery curves inward deeply beneath the flexor muscles, and passes along the ulnar side of the forearm, between and covered by the flexor carpi ulnaris and flexor sublimis digitorum; it is accompanied by two veins and by the ulnar nerve, which is more superficial and internal (Fig. 243). The forearm being supine, the hand extended and inclined to the radial side, make an incision on the imaginary line given, three inches in length and beginning three fingers' breadth below the internal condyle through the skin and superficial fascia, and recognize the aponeurotic connection of the flexor carpi ulnaris and flexor sublimis, which is of a yellowish-white color; divide it on the director from below, where it is the most delicate, carefully avoiding the division of muscular substance; the flexor sublimis, *a*, is drawn outward, and the deep aponeurosis exposed, under which lies the artery; if the vessel is not seen, press the flexor carpi ulnaris, *c*, inward, and expose the ulnar nerve, *b*, a little external to which lies the artery, *e*, with its two veins,

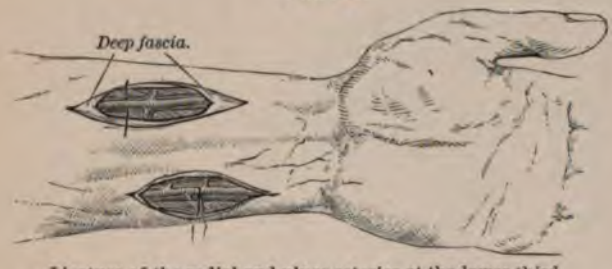
FIG. 243.

The ulnar artery in its upper third.

d; isolate the artery by flexing the arm slightly and the hand strongly; pass the needle from without outward.

(*b*) In its lower third the artery is superficial, having upon its inner side the flexor carpi ulnaris and ulnar nerve, and upon its external side the flexor sublimis digitorum. Place the arm supine and extend the hand so as to make prominent the tendon of the flexor carpi ulnaris; then along the radial border of this muscle (Fig. 244), or at the union

FIG. 244.



Ligature of the radial and ulnar arteries at the lower third.

of the external four-fifths of the arm with the internal fifth, or on a line drawn from the internal condyle to the pisiform bone, make an incision about two inches in length through the skin and subcutaneous cellular tissue; raise the deep fascia on a director or with the forceps, and incise it, exposing the tendon of the flexor carpi ulnaris; this should be pressed inward, and immediately behind it the artery will be found with its two accompanying veins, and the nerve upon the inside.

FIG. 245.

Ulnar artery at the wrist.

(*c*) At the wrist (Fig. 245) the artery lies to the radial side of the pisiform bone, and is accompanied by its veins, *b*, and the ulnar nerve, *c*, which lies on its internal and posterior aspect. The hand being held back, make a slightly curved incision on the radial side of the pisiform bone, through the skin and adipose tissue, about three inches in length, its concavity looking inward; the artery, *a*, is deeply seated in a groove, and the dissection should be continued along the side of the pisiform bone until it is exposed: the latter part of the dissection will be facilitated by flexing the hand upon the forearm; pass the needle beneath from within outward.

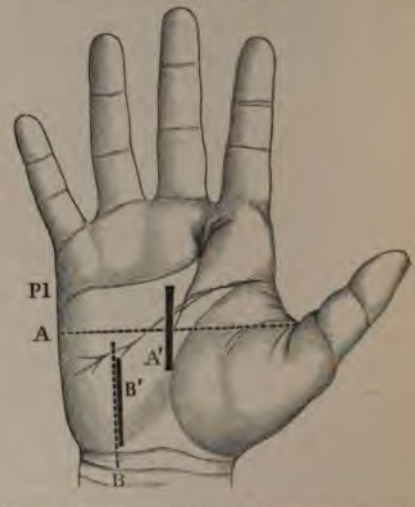
The *superficial palmar arch* is the continuation of the ulnar artery into the hand (Fig. 246). Near the lower border of the annular ligament this artery turns obliquely outward across the palm of the hand toward the middle of the muscles of the thumb, where it inosculates with a small branch of the radial, the superficialis volæ. At its commencement it rests on the annular ligament of the wrist and slightly on the short muscles of the little finger, then on the tendons of the superficial flexor of the fingers and the divisions of the median and ulnar nerves, the latter nerve accompanying the vessel for a short distance; it is cov-

ered toward the ulnar border of the hand by the palmaris brevis and the palmar fascia and integument. The central portion of a transverse line drawn across the palm, from the angle of the web between the thumb

FIG. 246.

Position and mode of formation of the palmar arches and distribution of the digital arteries.

FIG. 247.



Lines of incision: *A*, line indicating convexity of arch; *A'*, line of incision for arch; *B*, line indicating the cubital branch of the arch; *B'*, line of incision for this branch; *Pl*, inferior palmar fold (Chalot).

and index finger, corresponds pretty accurately with the position of the middle of the superficial palmar arch; if the thumb be abducted, its anterior surface is continuous in direction with the palmar outline of the ball of the thumb, which will then become parallel to the middle palmar fold; the vessel lies parallel to and equidistant between them (MacCormac). Make an incision one inch long midway between and parallel to these lines, and nearly opposite to the bases of the middle and ring fingers; divide the skin and palmar fascia, and the arch will be brought to view at the thicker part of the ulnar artery (Fig. 247).

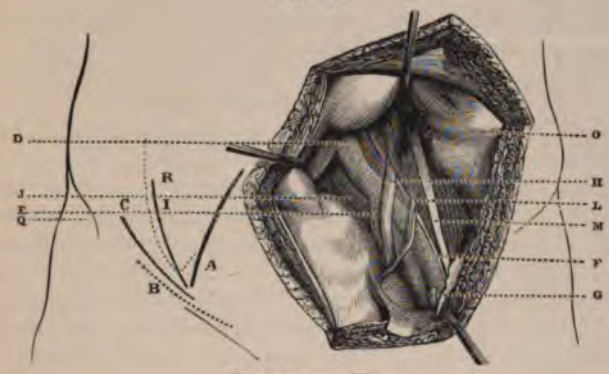
ARTERIES OF THE LOWER EXTREMITY.

The *abdominal aorta* lies in front and a little to the left side of the bodies of the vertebræ, having the vena cava on its right side, the sympathetic nerve on its left, and the left lumbar veins behind; it divides on the lower part of the fourth lumbar vertebra at a point nearly corresponding to the umbilicus; it may be ligated about one inch above its bifurcation, between it and the origin of the mesenteric. It can be exposed and successfully ligated by the operation for the common iliac: the artery being separated from the vein, with the finger or a director pass the needle from right to left. Or make an incision along the linea alba three inches in length, the middle of it on a level with the umbilicus, but a little to the left; open the peritoneum; push the intestines aside; detect the artery by its pulsations; separate the peritoneal covering with the finger-nail on the left side, carry the finger under the vessel

and pass the needle; or make an incision from the extremity of the tenth rib downward six inches, curving backward to within an inch of the anterior spine of the ilium, Q (Fig. 248), and reach the aorta from the side by raising the peritoneum. All the antiseptic precautions of peritoneal section must be enforced.

The *common iliac artery* (Fig. 248) varies from three-quarters of an

FIG. 248.



The common iliac.

inch to three inches in length, averaging about two; it passes from the bifurcation of the abdominal aorta on the left side of the body of the fourth lumbar vertebra, a point corresponding with the left side of the umbilicus, on a level with a line drawn from one crista ilii to the other, downward and outward along the margin of the pelvis to the sacro-iliac synchondrosis; the artery upon the right side is on an average the same length as that upon the left, and has in front the peritoneum and at its point of division the ureter. The following method of operating is now to be preferred: Provide large flat aseptic sponges, small sponges with sponge-holders, hot sublimate solutions for douche, spatulæ, and an aneurism needle armed with a carbolized silk or catgut ligature; cleanse the surface of the abdomen and empty the bladder. Make an incision in the median line four inches in length, commencing at the symphysis, through the superficial tissues down to the linea alba; ligate all bleeding vessels; open this aponeurosis at the upper end of the incision cautiously by raising a fold with forceps and cutting with the point of the knife; divide it throughout on the director; in the same manner incise the transversalis fascia, thus exposing the peritoneum; raise a fold of the peritoneum with forceps and open it with the point of the knife, and then enlarge the opening on the fingers. Now, with the flat sponges wrung out of hot bichloride solution, push the intestines gently upward until the region of the artery is fully exposed; if the intestines are so distended that they cannot be pushed upward out of the way, draw them gently out of the wound upon the abdomen, first covered with towels wrung out of the hot sublimate solution, and keep them covered with the hot sponges. Drawing the side of the wound toward the artery with a spatula, the vessel will be fully exposed; avoiding the ureter, pick up the sheath of the artery with forceps; open it with the point of

the knife on the inner aspect and uncover the vessel; pass the needle from within outward. After ligating the artery cut the ends of the ligature; with the small sponges remove the blood, if there is any, from the cavity; return the bowels gently with as little manipulation as possible.

If the operation be performed without opening the peritoneum, pursue the following method: The patient being placed on the back (Fig. 248), inclining to the opposite side, make an incision, R, commencing just anterior to the extremity of the eleventh rib downward, one and a half inches within the anterior superior spine, and terminating just above the internal ring by a sharp curve upward and inward of an inch; the entire length is about seven inches; divide the integuments and superficial fascia; then the three abdominal muscles; cautiously raise the fascia transversalis from the peritoneum, first at the upper part of the wound where the union is slightest; now gently elevate the peritoneum and press it inward from the iliac fossa toward the pelvis; the pulsations of the external iliac, F, are first recognized, and the finger carried upward along this vessel reaches the common trunk; the ureter, H, in front is carefully pushed aside, and the needle passed from within outward.

The *internal iliac artery*, E (Fig. 248), is an inch and a half in length, extending from the bifurcation of the common iliac downward and forward to the upper margin of the great sacro-sciatic foramen; it is in relation anteriorly with the ureter, H, which separates it from the peritoneum; posteriorly with the internal iliac vein; it rests on the sacral

FIG. 249.

Position and direction of the superficial incisions which must be made to secure the gluteal artery and the sciatic or pudic arteries: *A*, posterior superior iliac spine; *B*, great trochanter; *C*, tuberosity of the ischium; *D*, anterior superior iliac spine.

A, *B*, ilio-trochanteric line, divided into thirds. This line corresponds in direction with the fibres of the gluteus maximus muscle. The incision to reach the gluteal artery is indicated by the darker portion of the line. Its centre is at the junction of the upper with the middle third of the ilio-trochanteric line, and exactly corresponds with the point of emergence of the gluteal artery from the great sciatic notch.

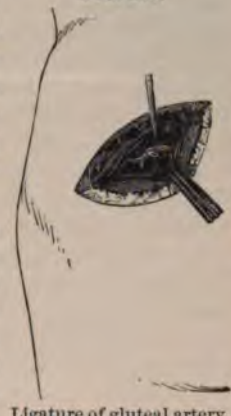
A, *C*, ilio-ischiatic line. The incision to reach the sciatic artery, or internal pudic, is indicated by the lower dark line. It is also to be made in the direction of the fibres of the gluteus maximus muscle. The centre of the wound corresponds to the junction of the lower with the middle third of the ilio-ischiatic line.

plexus of nerves and the pyriformis muscle; on the left the rectum lies partially over it. The artery may be exposed and ligated by the methods described in the operation on the primitive iliac.

The *gluteal artery* emerges from the pelvis at the upper part of the

great ischiatic notch, above the upper border of the pyriformis muscles. A line drawn from the posterior superior spine of the ilium to the top of the great trochanter marks the course of the artery (Fig. 249). In the operation (Fig. 250) place the patient in a prone position; make an incision on the line above indicated four or five inches long, terminating about an inch and a half from the spine; the cut is parallel with the fibres of the gluteus maximus, which should be separated, and the finger introduced to detect the pulsations of the artery; separate the pyriformis and gluteus medius muscles, the borders of which cover the vessel, and isolate the artery from its veins, and pass the needle as deeply as possible, as the artery divides just after its emergence.

FIG. 250.



Ligature of gluteal artery.

The *sciatic artery* escapes from the pelvis between the pyriformis and coccygeus muscles, and descends in the interval between the trochanter major and tuberosity of the ischium. It is covered by the gluteus maximus, and is accompanied by the sciatic nerve and the vein which lies to its posterior and inner side; the centre of a line drawn from the posterior superior spinous process of the ilium to the tuberosity of the ischium marks the point of exit of the artery from the pelvic cavity. The patient being prone, make an incision four inches in length, the centre of which falls upon the point of emergence of the artery, as given above (Fig. 249); divide the skin, cellular tissue, and the fibres of the gluteus maximus; the artery is found to the inside of the nerve, and must be carefully isolated from the vein.

The *internal pudic artery*, the smaller of the two terminal branches of the internal iliac, passes out of the pelvis through the great sacro-sciatic foramen, internal to the sciatic artery; it again enters the pelvis through the lesser sacro-sciatic foramen, runs along the ramus of the ischium and pubis, and divides into the arteries of the penis.

FIG. 251.

Ligature of internal pudic artery.

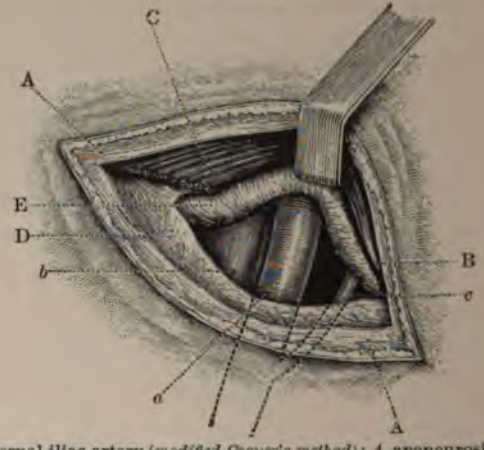
(*a*) At the greater sacro-sciatic foramen make the same incision as in the ligature of the sciatic artery; the pubic is found a little internal, accompanied by its veins and the pudic nerve.

(*b*) In the perineum (Fig. 251) the artery may be ligated as it descends the ramus of the ischium; draw a line from the middle of the pubes to the internal border of the tuber ischii. The patient being placed in the position for lithotomy, make an incision two inches in length along the ramus of the pubis, near the arch; the vessel is found along the inner border of the ramus, where it may be isolated and the ligature applied; care should be taken not to incise the corpus [illegible]m.

The *external iliac artery* (Fig. 252), four inches in l

liquely downward and outward from the sacro-iliac symphysis to Poupart's ligament, in a line drawn from the left side of the umbilicus to a point midway between the anterior superior spine of the ilium and the symphysis pubis. In its upper portion it has in front the peritoneum and intestines, and near Poupart's ligament the spermatic vessels, genito-crural nerve, circumflex iliac vein, lymphatic vessels and glands; externally, the psoas magnus, from which it is separated by the iliac fascia; internally, the external iliac vein; below and curving along its side, the vas deferens; behind, it rests above upon the external iliac vein, which gradually passes to its internal side. Place the patient in a recumbent position, the muscles relaxed by elevation of the pelvis; make an incision three or four inches in length, commencing about an inch and a half within the anterior superior spine of the ilium and on a level with this process, and extending in a curved direction downward and inward nearly parallel with Poupart's ligament, and terminating an inch and a half above it, just outside of the external abdominal ring. On the left side it will be found convenient to commence the incision internally, at the external ring and carry it upward and outward to the point indicated within the anterior superior spine. Incise the integuments and fascia, carefully avoiding the superficial epigastric artery; the aponeurosis of the

FIG. 252.



Ligature of right external iliac artery (*modified Cooper's method*): *A*, aponeurosis of external oblique; *B*, conjoined tendon; *C*, internal oblique; *D*, transversalis fascia; *E*, peritoneum; *a*, ext. iliac artery; *b*, ext. iliac vein; *c*, deep epigastric artery (Treves).

external oblique muscle is now exposed and divided on a director; in the same manner divide the fibres of the internal oblique and transversalis muscles until the transversalis fascia, recognized by its white opaque appearance, is exposed; cautiously open this membrane and incise on the director; the peritoneum is now exposed and carefully detached from the iliac fossa, and pushed toward the pelvis; the artery is readily felt pulsating at the bottom of the wound, along the inner border of the psoas muscle, the vein being on the inner aspect, the genito-crural nerve external; open the sheath and insinuate the needle from within outward to avoid the vein. Or the finger may be passed

into the internal ring along the spermatic cord and the iliac fascia raised in this manner. Other incisions are made in the course of the artery (Fig. 248, A), three inches in length; a curved incision (Fig. 248, C), commencing a little above the spine of the ileum, and terminating a little above the internal edge of the inguinal ring; an incision (Fig. 248, B) in the centre of the space between the interior spine and the symphysis pubis.

The *femoral artery* extends from Poupart's ligament to the tendinous opening in the adductor magnus muscle, at the junction of the middle and lower third of the thigh, in a line drawn midway between the anterior superior spine of the ilium and the symphysis pubis and the inner side of the internal condyle.

(*a*) The common femoral artery extends from Poupart's ligament to the origin of the deep femoral, about one inch and a half. It is superficial, being covered by the skin, superficial and deep fasciæ, and lymphatic glands; the vein lies on its inner side, and the anterior crural nerve half an inch to its outer side; the vessels lie in a canal formed by the parting of the two layers of the fascia lata, and are separated by this septum. Half or three-quarters of an inch below Poupart's ligament will be the most favorable locality for ligature (Fig. 253). The pulsation being recognized midway between the anterior superior spine of the ilium and the pubes, make an incision two inches in length over the artery, commencing over Poupart's ligament; divide the skin and cellular tissue; raise the fascia on a director and expose the sheath; open it, and examine for the origin of the profunda and epigastric; draw the vein inward and pass the needle around the artery from within outward, ligating it above the profunda femoris. The incision has been made parallel with Poupart's ligament. In persons of ordinary flesh the fold of the groin corresponds exactly with Poupart's ligament, but in those who are very fleshy the fold is somewhat below Poupart's ligament, and should this be taken as the guide to the commencement of the incision, there would be danger of applying the ligature just below the origin of the profunda; it is advisable to bring the ligament into view before the ligature is applied, and to pass the needle a finger's breadth below.

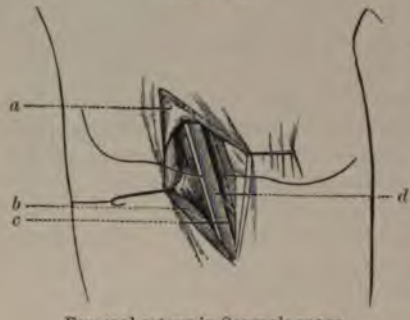
FIG. 253.

Ligature of right common femoral at base of Scarpa's triangle: *A*, line of Poupart's ligament; *B*, superficial fascia; *C*, fascia lata; *D*, sheath; *a*, femoral artery; *b*, femoral vein; *c*, internal saphenous vein; 1, genito-crural nerve (Treves).

(*b*) The superficial femoral artery lies in a triangle, Scarpa's space, formed by Poupart's ligament above as its base, the sartorius externally, and the adductor brevis internally; it is very superficial, being covered by integument, the superficial and deep fasciæ, and lymphatic glands; the vein is on the inner and slightly posterior part (Fig. 254). Abduct and place the thigh on its external aspect; make an incision, commencing about four inches below Poupart's ligament, along the inner margin of the sartorius muscle, three inches in length; the

vein, first made prominent by pressure above, is left to the inner side; divide the fascia lata, *a*, expose and draw outward the sartorius, *b*, and the sheath of the vessels becomes apparent; the position of the artery is recognized by its pulsations; open the sheath to a sufficient extent, and then pass the needle, very cautiously, from within outward to avoid the vein, *c*; the point of the needle should be kept close to the artery, *d*, as the vein lies closely on its inner and posterior aspect. If the saphenous vein is wounded, compression is sufficient for its treatment: if the incision falls upon the sartorius, this must be drawn aside.

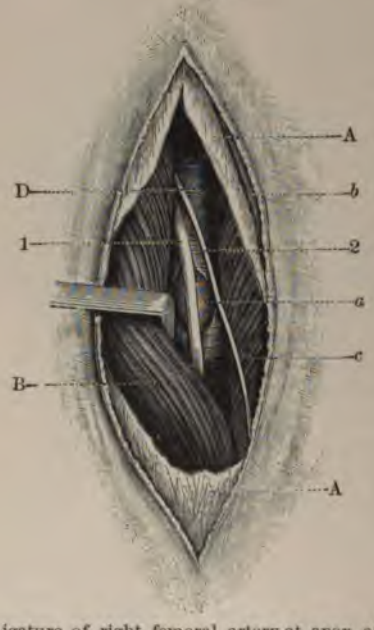
FIG. 254.



Femoral artery in Scarpa's space.

(*c*) The portion of the femoral artery at the apex of Scarpa's space (Fig. 255) is covered by the skin, superficial and deep fasciæ, and sartorius, and is contained in a fibrous canal; the femoral vein lies on the outer and posterior part of the artery, and the long saphenous nerve more externally. Place the limb in position, and make an incision three or four inches in length at the middle of the thigh, on the line given or on the inner border of the sartorius muscle, its upper extremity being six lines, and the lower two lines, from the internal

FIG. 255.



Ligature of right femoral artery at apex of Scarpa's triangle: *A*, fascia lata; *B*, sartorius; *C*, adductor longus; *D*, sheath of artery; *a*, femoral artery; *b*, tributary to internal saphenous vein; 1, long saphenous nerve; 2, internal cutaneous nerve (Treves).

FIG. 256.

The left femoral artery in Hunter's canal: *s*, sartorius drawn inward; *f*, fascia closing the canal, opened freely; *a*, the artery, with a small opening in its sheath for the passage of the needle; *s.n.* long saphenous nerve.

border of that muscle, care being taken to avoid the internal saphenous vein, the course of which is made apparent by compression above; expose

the sartorius by dividing the fascia lata; draw it outward; expose and divide the fibrous connection between the vastus and adductor muscles; the sheath of the vessel now appears, which is readily opened, and the needle passed from within outward, avoiding the vein and long saphenous nerve.

(*d*) At the inferior part of its course the femoral artery enters a fibrous sheath formed by the fibrous bands which extend from the vastus internus to the adductor magnus and longus, having over it the sartorius muscle, fasciæ, and integuments (Fig. 256). Flex the thigh on the pelvis, the limb resting on its external surface; make an incision three inches long on the outer margin of the sartorius muscle, if recognized, or on the line above given; the skin being divided, the sartorius recognized, and the fascia divided on a director, two lines within its external border, draw the muscle backward and divide the posterior part of its sheath; the space between the vastus internus and adductor magnus is now recognized, which contains the canal of the artery; open this canal on a director, and the artery is exposed, with the vein on its inside and the saphenous nerve on the outside; the vessels are united by very dense cellular tissue, and great care is necessary to isolate the artery.

The *popliteal artery* extends from the opening in the adductor magnus to the lower border of the popliteus muscle, in an oblique direction downward and outward. In the popliteal space the external saphenous vein runs perpendicularly in the median line; the popliteal nerve passes down the middle of the popliteal space, superficial to, and on the outside of, the popliteal vessels, from which it is separated by adipose tissue; the popliteal artery is covered in its whole course, and crossed at the middle of the popliteal space, by the popliteal vein, the direction of which is vertical; the artery, always beneath the vein, is somewhat internal to it above and external to it below; the vessels are covered superiorly by the belly of the semi-membranosus; below, they pass between the two heads of the gastrocnemius. They are connected together, throughout their course, by dense cellular tissue, which renders their separation difficult.

FIG. 257.

Left popliteal artery: *A*, popliteal artery; *V*, vein; *N*, internal popliteal nerve; *M*, biceps muscle.

(*a*) In its upper part make an incision three inches in length, from the inferior third of the thigh and passing along the external margin of the semi-membranosus muscle; divide the skin and fascia; separate the cellular tissue with the director and finger; now flex the leg, and the nerve first appears, then the vein on its inside, and lastly the artery; pass the needle from within outward.

(*b*) In its lower part (Fig. 258) the patient is laid on his face, and an incision made through the integument three inches long, slightly on the outside of the median line; the external saphenous vein, *c*, which lies under the skin, is carefully avoided; the fascia, *A*, is divided, and the cellular substance in the space between the two heads of the gastrocnemius is separated with the finger, exposing the popliteal nerve, 1, the vein, *b*, and most external, the artery, *a*; the nerve and vein are drawn inward, and the needle is passed from within outward.

The *posterior tibial artery*, a branch of the popliteal artery, extends from the lower border of the popliteus muscle, in an oblique direction, from without inward to the annular ligament; its course is in a line commencing in the centre of the popliteal space and terminating behind the internal malleolus.

FIG. 258.

Ligature of right popliteal (lower part): *A*, fascia; *B*, gastrocnemius; *a*, popliteal artery; *b*, popliteal vein; *c*, external saphenous vein; 1, internal popliteal nerve; 2, muscular branches; 3, external saphenous nerve.

(*a*) In its upper third the artery is covered by the tibialis posticus, the deep aponeurosis, the soleus, and the gastrocnemius. The limb being placed on its outer side, the knee flexed, make an incision at least four inches in length, at a distance of two-thirds of an inch from the internal border of the crest of the tibia through the integuments and deep fascia; carry the index finger into the wound, detach and push outward the internal head of the gastrocnemius, and divide also the attachments of the soleus, thus exposed, from the posterior surface of the tibia; whilst an assistant keeps this muscle held backward and outward with a blunt hook, divide the deep layer of aponeurosis upon a director, and search for the vessel immediately beneath; detach the artery, and pass the ligature beneath it with the artery needle.

(*b*) In its middle third the artery runs parallel with the inner border of the tibia, from which it is separated by the flexor longus digitorum; it is covered by the internal border of the soleus, it has venæ comites, and the posterior tibial nerve is on its inner side. The limb is placed as in the last position, and an incision made three inches in length, three-fourths of an inch posterior to the internal border of the tibia; the integument and deep fascia being divided, the fore border of the gastro-

FIG. 259.

Ligature of the posterior tibial artery in its middle third.

cnemius is seen and drawn backward, exposing the soleus; the fibres of this muscle should be divided on a director; the artery is now felt pul-

sating about an inch from the margin of the tibia; the pearl-colored deep aponeurosis which overlies is divided, and then the muscles relaxed by the position of the limb; the artery is isolated from its veins, the nerve being pressed to the outside; the needle is passed from without inward (Fig. 259).

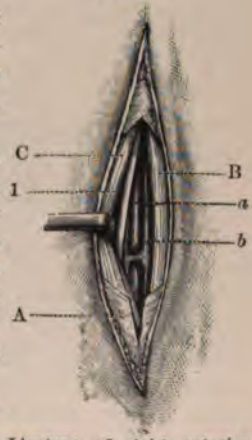
(*c*) In its lower third the artery passes behind the internal malleolus, at first parallel with the tendo Achillis, and then midway between the internal malleolus and the tuberosity of the os calcis; it is very superficial, and is in relation anteriorly with the tendons of the tibialis posticus and flexor longus digitorum, and posteriorly with the posterior tibial nerve; it has venæ comites (Fig. 260). The leg being placed on its external aspect, the foot flexed, make an incision, two inches in length, a finger's breadth posterior to the inner edge of the tibia and parallel with it; the integuments are divided; the deep fascia raised on a director, and a small mass of fat opened, which will expose the artery and the venæ comites and the posterior tibial nerve; the sheath of tendons should be carefully avoided; it should be noticed that the artery sometimes lies anterior to the incision here given. The artery may be ligated a little lower by making a curved incision one-third of an inch behind the external malleolus. At this part of the leg the anastomoses of large branches of the internal saphenous vein are numerous, and generally run transversely; these may be brought out by compressing the trunk of the vein above, and thus be avoided, at least in part.

FIG. 260.

Ligature of posterior tibial artery behind inner malleolus.

The *anterior tibial artery* emerges upon the anterior part of the leg, at its upper part, through the interrosseous membrane, about the level of the lower margin of the tuberosity of the tibia, and passes down to the ankle, in a line drawn from the inner side of the fibula to a point midway between the two malleoli; the anterior tibial nerve is closely applied to the outside of the artery throughout; it may be ligated at any point in its course.

FIG. 261.



Ligature of right anterior tibial artery (upper third): *A*, fascia of leg; *B*, tibialis anticus; *C*, extensor communis digitorum; *a*, anterior tibial artery; *b*, anterior tibial veins; 1, anterior tibial nerve.

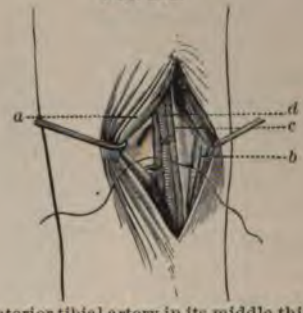
(*a*) In its upper third (Fig. 261) the artery lies between the tibialis anticus and extensor longus digitorum, which have their origin in part from the deep fascia, hence the intermuscular septum is not easily recognized, nor are the muscles readily separated. The limb being turned inward and the foot extended, take as a guide the line already given, or a point ten lines to the outer side of the spine of the tibia, and make an incision about four inches in length through the integument; divide the

deep fascia with a crucial incision to allow of its complete separation; the intermuscular septum is now sought for, and may be recognized: (1) as the first intermuscular space from the tibia; (2) on pressure from within outward by the resistance of the other muscles; (3) by the fact that at the lower part of the wound the white line of the muscular interspace is more marked. The foot being flexed, separate the muscles with the index finger, and, the wound being held apart, expose the artery with its two veins and nerve, the latter being outside; pass the needle from without inward, avoiding the nerve.

(*b*) In its middle third the artery is covered by the deep fascia; on the inner side it has the tibialis anticus muscle, and on the external the extensor longus digitorum and extensor proprius pollicis (Fig. 262). The limb being placed as in the former position, make an incision three inches or more in length in the course of the artery, as above given; the septum in the deep fascia uniting the two muscles is recognized by a white line; divide it longitudinally and also by a crucial incision; flex the foot to relax the muscles, and, the wound being separated by drawing the tibialis anticus, *b*, internally and the extensor longus digitorum and extensor proprius pollicis externally, the nerve is met with more superficially than the artery, *d*, with its veins, *c*; pass the needle from within outward, avoiding the nerve.

(*c*) In its lower third (Fig. 263) the artery

FIG. 262.



Anterior tibial artery in its middle third.

FIG. 263.

Ligature of right anterior tibial artery (lower third): *A*, anterior annular ligament; *B*, tibialis anticus; *C*, extensor proprius pollicis; *a*, anterior tibial artery; *b*, anterior tibial veins; l, anterior tibial nerve.

is covered by the fascia, and is crossed by the extensor proprius pollicis; it lies at first between the tibialis anticus muscle and the extensor proprius pollicis, the latter muscle crossing to the inner side; the artery lies between the tendon of this muscle and that of the extensor longus digitorum; it is accompanied by venæ comites and the anterior tibial nerve, which here lies to the outer side. The leg being placed in a horizontal position, the foot extended, and the tibialis anticus muscle recognized, make an incision along the external border of that muscle, on the line already indicated, three inches in length, but not extending to the annular ligament; carefully incise the deep fascia on a director, and find the space between the tibialis anticus and extensor proprius pollicis, and

separate the two muscles with the index finger; now flex the foot, and expose the artery resting on the tibia with the nerve superficial to it; isolate it from the two veins, and pass the needle from within outward, the nerve being drawn inward. If the incision falls between the extensor proprius pollicis muscle and the extensor communis digitorum, the ligature may still be applied.

The *dorsalis pedis artery* terminates the anterior tibial, and runs in a line drawn from the middle of the intermalleolar space, measured from the extremities of the malleoli, to the space between the first metatarsal bones. It is covered by the integuments, fascia, and innermost tendon of the extensor brevis digitorum; on its inner side is the extensor proprius pollicis, and externally, the inner tendon of the extensor longus digitorum; on its external aspect is the anterior tibial nerve. Make an incision (Fig. 264) two or three inches in length parallel to the

FIG. 264.

Ligature of dorsalis pedis artery.

external border of the tendon of the extensor proprius pollicis muscle; divide the skin and deep fascia on a director, and draw the internal division of the extensor brevis digitorum outward, exposing the artery and its accompanying veins; the nerve is on the outside; pass the needle from within outward.

THE RESECTION OF BONES.

Resection of a bone, in part or whole, is required after injuries which have destroyed its vitality, or after diseases which have resulted in caries or necrosis, or in the removal of tumors; but the operation is justifiable only when it is evident that resection is preferable to every other remedial measure. When undertaken it must be so planned and executed as to become the first step in a process of repair by which

a part that would otherwise have been sacrificed is restored to more or less complete usefulness. The operation must be determined by the condition of the patient and of the diseased part. As a rule the operation is indicated only when the general health admits, for if the patient is suffering from a progressively wasting disease, as tuberculosis or marasmus, which will necessarily prove fatal, resection would be unwise, as repair would not follow. In injuries, as gunshot, only such fragments of bone should be removed as are nearly or quite detached from the periosteum. In caries of a hollow bone the ulcer may be thoroughly cleaned out with the gouge and the cavity be allowed to close by granulation, but if the bone is small extirpation may be necessary to arrest the process at once. If a hollow bone is affected throughout, as with periostitis, external and internal caries, or partial internal and external necrosis, extirpation of the entire bone may be required as the only alternative of amputation. Tumors of bone, if not malignant, must be removed from their locality, but if malignant, extirpation of the bone or wide resection is necessary.

Resection of a joint is necessary for such shot injuries as the comminution of the ends of the bones, or the impaction of a ball in the end of the bone in such manner that it cannot be removed without destruction of the bone; in compound dislocation with extensive injury of the soft parts, or complicated with fracture, and in caries which has destroyed the articular surface and continues to progress in spite of well-directed efforts to control it. Compound dislocations and fractures involving joints, once so fatal from inflammation, do not now always necessitate excision, for when antiseptic methods are rigidly enforced from the first suppuration does not occur.

The *time* of operating after an injury, as a gunshot, should, if possible, be within twenty-four hours of the accident, or primary; if it is delayed beyond this period, it should not be performed until the intermediary stage of inflammation is passed. If the bone is necrosed, the rule should be not to attempt removal before complete, or nearly completed, detachment, because the dead bone can rarely be taken out without removing healthy and newly-formed bone, and the new bone is not firm enough before the sequestrum is detached.

The *instruments* required in resection and excision may be few or many, both in number and variety, according to the nature of the case. (1) The knife (Figs. 265 and 266) should be broad and firmly set in

FIG. 265.

FIG. 266.

Scalpels.

a rough handle, which may or may not terminate in a periosteotome (Fig. 266). (2) The retractors may consist of broad metal plates properly curved (Fig. 267) or take the form of hooks; the latter

Fig. 267.

Retractor.

are less liable to slip out of the wound, but do not so effectually open it. (3) The periosteotome takes many forms (Figs. 268, 269); it is always a blunt instrument, and in its use care must be taken not to contuse the peri-

Fig. 268.

Fig. 269.

Periosteotomes.

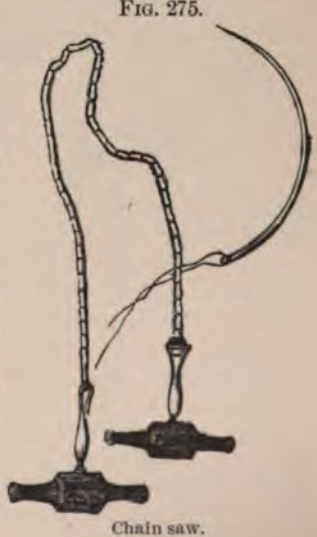
osteum when it is desirable to preserve its function. (4) The bone-cutting instruments are numerous and important. The straight bone for-

Fig. 270. Fig. 271. Fig. 272. Fig. 273. Fig. 274.

Cutting forceps.

ceps (Fig. 270) is a most useful instrument in the section of the small bones wherever it can be brought to bear. But frequently it is quite difficult to reach the part, which may be more readily divided with the forceps than the saw unless the blades are curved at a considerable angle; in such cases a forceps curved (Figs. 271 or 272) will be found serviceable. The bone-gnawing forceps (Figs. 273, 274), or rongeur, is indispensable in many resections, as it enables the operator to remove projecting parts not accessible to other instruments. The saw in one of its various forms is necessary. The chain saw (Fig. 275) consists of a number of pieces, with movable articulations, terminated at each extremity by handles with which it is worked. To use this saw, one handle is removed from the hook, and a needle, armed with a strong thread, is attached to the end; the needle is passed under the bone, and the saw drawn into its position, with the cutting edge upward, and the handle is then re-attached;

Fig. 275.

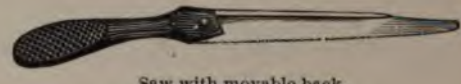


Chain saw.

the operator, grasping the handles, draws the saw alternately from side to side, until the bone is divided: there is great danger of breaking this saw if it is worked carelessly; it should be drawn from side to side steadily, at an angle of 45° to the long axis of the bone. The sections may consist of metallic beads strung on a wire with handles; such a saw will act efficiently in whatever direction it is held.

Other saws, of peculiar shape, are often useful in the removal of certain bones, though not absolutely essential; the saw (Fig. 276) with

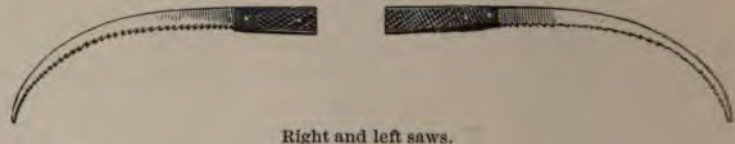
FIG. 276.



Saw with movable back.

a movable back may be used to advantage in most resections of bones of the extremities; in the removal of the superior maxilla the right and left bone saws (Figs. 277, 278) enable the operator to separate its supe-

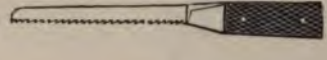
FIG. 277. FIG. 278.



Right and left saws.

rior attachments with great facility; a small straight saw (Fig. 279) is often required, and when it is necessary to use a part of the edge an india-rubber tube may be drawn over the part unused to prevent its

FIG. 279. FIG. 280.



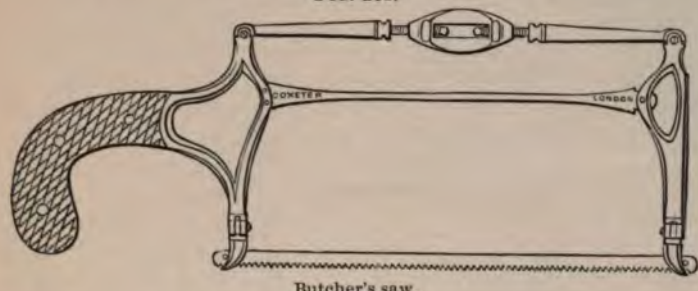
Straight-back saw.

Hey's saw.

injuring the soft parts; occasionally a saw having a circular as well as a straight edge (Fig. 280) is required in removing sharp points or thin bones; a saw concealed in a sheath is very useful in subcutaneous division of bones (G. F. Shrady); finally, a saw is essential which may be taken from its position (Fig. 281), where it is firmly held by a spring connected with the handle, and passed under the bone, if required, and the ends, being re-attached in the frame, the bone is as readily divided from beneath as from above; the saw may be turned laterally also or be made to cut in a curve; the tension of the saw is regulated by a spring enclosed in the handle. Bone drills for the introduction of the wire suture must be provided, and an osteotrite will often be necessary (Fig. 282). The gouges, the chisel (Fig. 283), and the mallet (Fig. 284), are

often required; to thoroughly clean out all forms of carious cavities two or more gouges and spoons are necessary with different cutting edges;

FIG. 281.



Butcher's saw.

the mallet may be of wood or metal with a firm handle. (5) The seizing forceps may be the common dressing forceps (Fig. 285) for small frag-

FIG. 282.

Drills.

ments, and larger forceps for large fragments (Fig. 286); they should also have straight and curved beaks (Figs. 287, 288) to seize fragments

FIG. 283.

Chisel and gouges with adjustable handle.

FIG. 284.

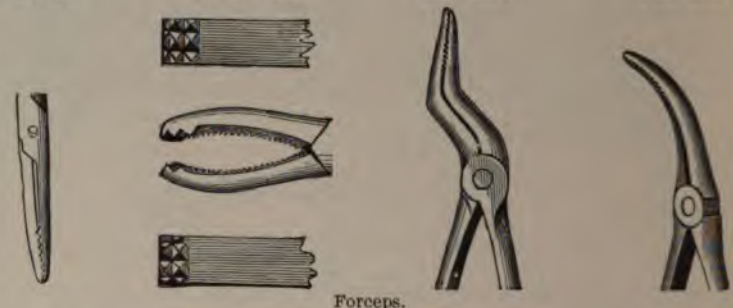
Mallet.

that are concealed. The bone scoop (Fig. 289) is necessary in removing all the dead tissues in bone-cavities.

An instrument capable of seizing the bone and holding it in position

while a saw adjusted in it can be so operated as to divide the bone is often desirable. Such an instrument has been devised, and in modified

FIG. 285. FIG. 286. FIG. 287. FIG. 288.



Forceps.

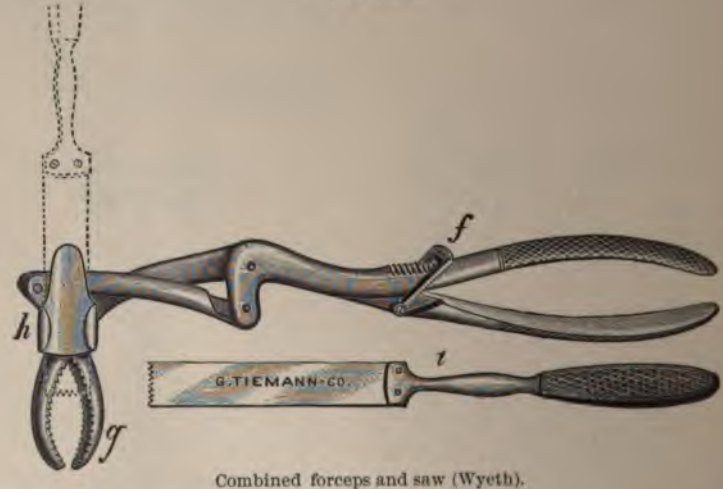
form (Fig. 290) has proved very useful. It consists of handles having a fixation clamp, *f*; by opening or closing the handles the jaws, *g*, are

FIG. 289.

Bone scoop.

separated or closed; the saw, *l*, is in shape like a chisel and works in a shield, *h*. The bone to be exsected having been exposed, with its peri-

FIG. 290.



Combined forceps and saw (Wyeth).

osteum peeled off in common with all the circumjacent tissues, the operator, holding the handle of the instrument in his left hand (the saw

being entirely removed), opens the jaws, *g*, wide enough to insinuate them about the bone; as soon as this is accomplished, with the right hand slide the saw into the shield, *h*, down until the teeth engage against the bone; a slight oscillation of the handle of the saw with requisite pressure carries it through the bone with remarkable rapidity and without wounding or bruising the contiguous soft tissues.

The *preparations for the operation* are as follows: Cleanse the hands and nails with soap, water, and nail-brush and wash them in bichloride solution; put the instruments in the tray and cover them with carbolic-acid solution 1:20; prepare the solution of bichloride, 1:2000, in the irrigator, the water being hot. The parts to be operated should be antiseptically prepared on the preceding day, and wrapped with aseptic dressings. Bind towels, wrung out of the bichloride solution, around the limb, one above and one below the point, and spread others over all the region of the wound, so as to protect the hands and instruments from contact with soiled surfaces or materials. Apply the elastic bandage unless the parts are infiltrated with pus.

The *operation* is as follows: (*a*) In the removal of the bone the method of operating must be adapted to each particular case. In shot fractures the extirpation of fragments must be through openings extending from the wound; in necrosis the sinuses are guides for incisions; in the excision of the bone for morbid growths the incisions must be largely in the direction of the tumor. The incision in general should be made as nearly as possible over the bone to be removed and parallel with arteries, nerves, and muscles. The soft parts should not be destroyed, except so far as they have undergone degeneration or interfere with the proper closure of the wound. Injuries to blood-vessels and nerves lying in the track of the incision should be scrupulously avoided by drawing them aside; muscles and tendons should, if possible, not be divided nor their attachments incised, but should be separated to the necessary extent with a blunt instrument. The bone being exposed, the operator should preserve in the wound, and, as far as possible, in its original position, the periosteum of the bone to be removed, in order to the reproduction of sufficient new bone to preserve the function of the part. The periosteum is best preserved by first incising it to the extent of the bone to be removed, and then separating it with the periosteal knife or the end of the scalpel. The periosteum being separated, the bone must be divided by cutting forceps or the saw, and each portion separately removed; if the saw is used, the soft parts should be carefully protected by compresses or a spatula introduced underneath the bone. In some cases the interior of carious cancellated bones may be scooped out and the external shell be left as the basis of new bone. The scoop may be a curved chisel, the periosteal knife, or other instrument which can be applied to the interior of the carious cavity.

(*b*) In the resection of joints the operator should aim (1) to remove all diseased structures without needlessly sacrificing parts; in children, especially, the epiphyses of bones must be preserved with the most scrupulous care, to ensure their future growth; in adults the amount of bone removed will always have regard to the future usefulness of the joint. (2) If the functions of the joint are to be preserved, as of the upper extremities, the fibrous structures must be saved in their proper relations;

the periosteum must be preserved with the attachments to the capsule; the muscular attachments must be separated uninjured or with the bony fragments of their insertions, to ensure their future usefulness; the bones may be so shaped and placed in position as to maintain their special movements, preserving even a useful hinge-joint at the elbow. (3) If the joint is to be ankylosed, as the knee, the surfaces of the excised bones must be accurately applied and maintained to secure firm union. The bones may be maintained in apposition by wire, catgut, prepared silk, and by nails and metallic pins driven through the fragments. The silver wire is, in general, the best material for that purpose. It should be so inserted as not to require removal—viz. after being twisted, cut it off and turn the twisted ends downward between the extremities of the bones.

The **treatment** of resection wounds should secure rest, and freedom from irritation. Rest is obtained by apparatus adapted to each case; in general the immovable apparatus of plaster of Paris is most available and useful. Though these wounds usually heal by granulation, yet by careful attention to the use of antiseptics suppuration may be entirely prevented. They are peculiarly liable to be poisoned by septic ferments from the putrefactive matters already existing in the wound. The dressings should, therefore, be scrupulously antiseptic throughout the stage preceding granulation and subsequently to such degree as will protect the granulations from any infectious matter which may enter or form in the wound. Irrigate the wound after the operation with bichloride solution, 1 : 2000; remove every particle of dead tissue; apply drains to every recess which will retain fluids; and close the wound with sutures to the fullest extent practicable. Apply iodoform dressings covered with bandages of bichloride or carbolized gauze, and finally two or three layers of plaster-of-Paris bandages. Re-dress at intervals of several days only, or when there are indications of disturbances in the wound.

BONES AND JOINTS OF THE UPPER EXTREMITIES.

Resection is to be preferred to amputation in the greater number of lesions of the upper extremities, as the principal function involves that of mobility.

The *phalanges* may be resected in part or whole, but the results are not always favorable, owing to the stiffness, shortening, and deformity which so often follow. The incisions should be on the side of the joints to be excised. Efforts should be made to preserve the periosteum with a view to the production of new bone in the shafts of the bones that have been removed. In the after-treatment apply a splint to the palmar surface, and make such extension as will maintain the full length of the phalanx. The entire phalanx is removed by an incision over the shaft of the bone on the side; the tendons being raised, introduce the bone forceps, divide the bone, and remove the two halves separately at their articulation. In removing the third or ungual phalanx make on the palmar surface a double T-incision, one end corresponding to the articulation, the other to the extremity of the finger; denude the phalanx from the end toward its base, the nail remaining intact.

The Metacarpal Bones.—The superficial condition of the dorsal aspect of these bones and the important anatomical relations of their

palmar surfaces require that all operations for their excision be commenced on the posterior part or dorsum.

(*a*) The entire bone is removed as follows: Make an incision along the dorsal surface of the third and fourth metacarpal bones, avoiding the extensor tendons, and on the radial side of the second and ulnar side of the fifth; draw the extensor tendon on one side and relieve the sides of the bone of the soft parts; separate the periosteum as much as possible and divide the centre with the bone forceps (Fig. 291) or with the chain saw, the soft parts being protected by a compress or spatula; the fragments are then separately elevated, and disarticulated with the point of the knife (Fig. 292). This operation may be variously modi-

FIG. 291.

Resection of metacarpal bone.

FIG. 292.

Resection of the proximal end.

fied, according to the condition of the part affected. When there is much swelling make a short lateral incision at each extremity of the longitudinal cut. The incision may also be made between the tendons of the long and short extensors on the dorsum along the radial border. In resection of the metacarpal the cut may be a T or an L.

(*b*) The shaft is removed by a longitudinal incision on the radial border of the first and second, on the ulnar border of the fifth, and the dorsal surface of the third and fourth; carefully avoid the extensor tendons, and with a chain saw or cutting forceps divide at two points the denuded bone.

(*c*) The proximal portion of the bone is resected by a longitudinal incision over the upper extremity of the metacarpal bone; avoid the extensor tendon, separate the soft parts from the sides of the bone; divide the bone at the requisite point with bone forceps or with the saw, after being isolated from the soft parts, and as far as possible from the periosteum; seize the fragment with the forceps; raise it from its bed (Fig. 292), and disarticulate the joint with the point of the knife.

(*d*) In complete resection the extremity of the metacarpal bone and

its corresponding carpal bone are removed by a single longitudinal incision made over the superior extremity of the metacarpal bone, which is denuded of soft parts and sawn at the proper point; remove this part at its articulation, and then extirpate the carpal bone.

(*e*) The phalangeal extremity of the metacarpal bone of the thumb is removed thus: Make an incision on its dorsal surface; draw aside the extensor tendons carefully; divide with a chain saw at the proper point; seize the diseased portion with the forceps, bring it forward and expose the articular extremity with the point of the knife, by which it is readily disarticulated.

The *phalangeal joints* should be excised by an incision along the side, slightly convex downward; through a single incision the extremities of the bones may often be reached and excised by turning them outward. In the treatment make sufficient extension by means of a palmar splint to keep the bones apart, and begin passive flexion as soon as repair is established.

The *metacarpo-phalangeal joints* should be excised by dorsal incisions along the margin of the extensor tendons, which must be drawn on one side; the articular surfaces being cleared, excise them with cutting forceps, a fine saw, or chain saw. The treatment is the same as after excision of the phalangeal joints.

The *wrist-joint* is properly limited to the articular end of the radius and the first row of carpals. But excision at the wrist includes the removal, not only of the radius and first row of carpal bones, but of a part or whole of the ends of the radius and ulna, a part or whole of the carpus, the proximal ends of the metacarpal bones, or all of these at once. The radio-carpal articulation is formed between the radius and triangular fibro-cartilage above and the scaphoid, semilunar, and cuneiform bones below; the carpal articulations are arthroidal; the synovial sacs are so arranged that their communications are limited: this anatomical peculiarity should be remembered in the effort to remove portions of the carpus, as it is desirable not to open these cavities farther than is absolutely necessary; the ligaments are dorsal, palmar, and interosseous.

There are several methods of operation, but those devised by Lister, Ollier, and Boeckel are to be preferred.

(*a*) Lister's excision of the entire wrist consists of a series of operations, each of which must be executed with scrupulous care, as follows: Break down adhesions of tendons by freely moving all the articulations of the hand; commence the first incision at the middle of the dorsal aspect of the radius, *A* (Fig. 293) on a level with the styloid process; carry it toward the inner side of the metacarpo-phalangeal articulation of the thumb, running parallel in this course to the extensor secundi internodii; on reaching the line of the radial border of the second metacarpal bone carry it downward longitudinally half the length of the bone, the radial artery lying farther to the outer side of the limb; detach the soft parts from the bone at the radial side of the incision, the knife being guided by the thumb-nail; divide the tendon of the extensor carpi radialis longior at its insertion into the base of the second metacarpal bone, and raise it along with that of the extensor carpi radialis brevior, previously cut across, and the extensor secundi internodii, while the radial

is thrust somewhat outward; separate the trapezium from the rest of the carpus by cutting forceps applied in the line with the longitudinal part of the incision; leaving the trapezium in position until the rest of the carpus is taken away, dissect the soft parts on the ulnar side of the incision from the carpus as far as convenient, the hand being bent back to relax the extensor tendons of the fingers; commence the second incision, *B* (Fig. 293), on the palmar surface, at least two inches above the end of the ulna, immediately anterior to the bone, and carry it downward between the bone and flexor carpi ulnaris, and on in a straight line as far as the middle of the fifth metacarpal bone on its palmar aspect; raise the dorsal lip, cut the extensor carpi ulnaris at its insertion into the fifth metacarpal bone, and dissect it from its groove in the ulna without isolating it from the integuments; separate the extensors of the fingers from the carpus, and divide the dorsal and internal lateral ligaments of the wrist-joint; leave the connections of the tendons with the radius undisturbed; now clear the anterior surface of the ulna by cutting toward the bone, avoiding the artery and nerve; open the articulation of the pisiform bone, and separate the flexor tendons from the carpus, the hand being depressed to relax them; clip through the base of the process of the unciform bone with pliers, but avoid carrying the knife farther down the hand than the bases of the metacarpal bones; divide the anterior ligament of the wrist-joint; separate the carpus from the metacarpus with cutting pliers, and extract the carpus with sequestrum forceps through the ulnar incision, dividing any ligamentous attachments; the articular ends of the radius and ulna may be protruded at the ulnar incision and excised; divide the ulna obliquely with a small saw so as to take away the cartilage-covered rounded part over which the radius sweeps while the base of the styloid process is retained; clear the radius sufficiently to remove the articular surface; if the caries is slight, remove a thin slice without disturbing the tendons in their grooves on the back of the bone; clip away the articular facet of the ulna with bone forceps applied longitudinally; if the caries is extensive, remove freely all the diseased bone with pliers and gouge; examine the metacarpal bones and excise the articular surfaces only if they are sound, and more extensively if diseased; next seize the trapezium with strong forceps, and dissect it out without cutting the tendon of the flexor carpi radialis, and excise the end of the metacarpal bone; clip off the articular facet of the pisiform bone, and, if sound, leave the remainder in position; close the radial incision firmly throughout with sutures, and also the ends of the ulnar incision, but the middle must be kept open by pieces of lint

FIG. 293.

Excision of wrist: *A*, Lister's radial incision; *B*, Lister's ulnar incision; *C*, Ollier; *D*, Boeckel.

introduced lightly to give support to the extensor tendons and afford free escape of discharges.

(*b*) In Boeckel's operation the incision may be made from the middle of the ulnar border of the metacarpal bone of the index finger upward to the middle of the dorsal surface of the epiphyses of the radius, *D* (Fig. 293), crossing to the ulnar side of the extensor carpi ulnaris at its insertion into the base of the third metacarpal bone, and dividing the dorsal ligament of the carpus between the tendons of the long extensor of the thumb and the extensor indicis; the soft parts being raised through this incision by careful manipulation of the hand, the carpal bones may be removed, one by one, by dividing the ligaments which bind them together and to other bones.

(*c*) Ollier makes an incision, *C* (Fig. 293), from an inch below the styloid process of the radius upward along the external border of that bone, to a sufficient extent; a branch of the radial nerve being preserved, the extensor tendons of the thumb are exposed and drawn aside and the insertion of the superior longus exposed. With a periosteotome detach the tendon of the supinator; denude the end of the radius of the periosteum and bend the carpus forcibly inward, dislocating the head of the radius outward. After separating the fibrous attachments excise the requisite amount. The end of the ulna may be reached through the same wound, or an incision along the inner border will expose it.

The after-treatment must be pursued with due recognition of the fact that the new joint at the wrist is produced by an approximation of the bones of the forearm and of the metacarpus, partly by shortening of the limb and partly by the growth of new bone from the divided ends; with proper care, perfect symmetry of the hand can always be ensured, for as the radius and ulna above and the metacarpus below are divided in parallel lines, the shrinking of the new material between them draws the hand equally upward toward the forearm: the surgeon should aim to maintain flexibility of the fingers by frequently moving them, and at the same time to procure firmness of the wrist by keeping it securely fixed during the process of consolidation. These indications are met by placing the limb on Lister's splint (Fig. 294), which consists

FIG. 294.

Hand after excision of wrist, laid in splint.

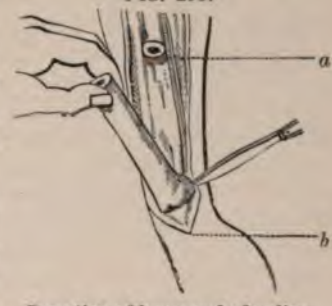
of an obtuse-angled piece of thick cork attached to a splint, with a cross-bar of cork attached to the under surface about the level of the knuckles; on the splint the hand lies semi-flexed, its natural position, the fingers midway between the extremes of flexion and extension, into which it is necessary to bring them in the daily passive movements; the thumb is to be kept from the index finger by a pad of cotton maintained between

them; flexion and extension of the fingers should be commenced on the second day whether inflammation has subsided or not, and continued daily, each finger being flexed and extended to the fullest degree possible in health, care being taken that the metacarpal bone concerned is held steady; pronation and supination must not be neglected, and, as the wrist acquires firmness, flexion and extension, adduction and abduction, should be occasionally encouraged; passive motion must be continued until there is no longer a tendency to contract adhesions.

The *radius* may be resected for necrosis with excellent results, the mortality being small and the usefulness of the hand and wrist being well preserved. In the after-treatment secure rest by a wire, tin, or sole-leather splint applied to the inner surface of the arm and forearm, and use iodoform dressings.

(*a*) The lower extremity is broad, of a quadrilateral form, having two articular surfaces, one concave, on the lower part, for articulation with the scaphoid and semilunar bones; the other, on the inner side, narrow and concave, to articulate with the lower end of the ulna. Make a longitudinal incision along the radius on its external anterior border (Fig. 295), extending downward to a point opposite and a little behind the styloid process; if necessary, add two terminal incisions at the extremities of the first one; remove the periosteum, and make section of bone by means of the chain-saw; isolate the lower part of the radius from its attachments at the radio-carpal articulation, without injury to the artery (*a*), nerves, or tendons.

FIG. 295.



Resection of lower end of radius.

(*b*) For the middle portion make a long straight incision on the external aspect of the bone parallel with its shaft; denude the bone, divide it at the two points selected, and raise the fragment from its bed, leaving the periosteum.

(*c*) The head of the radius is quite superficial on its posterior part and surrounded by the orbicular ligament, which retains it in the lesser sigmoid cavity of the ulna. Resect by making a straight incision on the posterior and external part of the arm over the bone, divide the bone cautiously, and raise it from its articulation by cutting the ligaments with the point of the knife.

(*d*) In excision of the entire radius make an incision along the outer surface of the radius from the styloid process to the head of the bone at the elbow-joint; divide the fascia along the outer border of the supinator longus muscle, and separate the muscles along this line down to the bone; incise the periosteum the length of the wound and separate it from the bone; divide the bone in the middle and remove each extremity separately.

The *ulna*, like the radius, may be resected for necrosis with very favorable results, both in regard to mortality and usefulness of the limb; but for shot injuries the mortality is in the aggregate augmented by operative interference, except when antiseptics are employed. The after-treatment is the same as in resections of the radius.

Removal of the lower extremity and the middle portion of the shaft is effected by the same methods as those given for the radius.

The upper extremity, including the olecranon, is exsected as follows: Make a longitudinal incision, five inches in length, over the middle of the olecranon, extending three inches above and two below it, penetrating to the bone; divide the triceps tendon at its insertion toward either edge, care being taken to avoid cutting across the aponeurosis, which is continuous from the edges of the tendon over the muscles lying on the posterior part of the forearm and inserted into the edges of the olecranon; dissect up these insertions of the fascia, as well as the origins of the muscles beneath it, from the bone to the extent of nearly two inches, which allows the olecranon to be exposed, when the edges of the incision may be drawn asunder over the condyles, broad, curved spatulæ being used for this purpose; with the amputating saw cut through one-half the thickness of the bone; complete the section with a fine saw, after which separate completely with a chisel and mallet.

The entire ulna may be removed by the following method: Rotate the limb inward from the shoulder-joint, and carry the pronation of the forearm so far as to cause the palm of the hand to look directly outward; slightly flex the elbow-joint and elevate the hand; this twisted position places the ulna upon the posterior and outer aspect of the forearm, and renders it more easily accessible; the limb thus placed, the assistants maintaining the arm and forearm steadily, make an incision along the posterior and inner aspect of the ulna, commencing at the lower part of its superior third and extending downward to a point over the extremity of the styloid process, make a transverse incision, about an inch long, from the lower extremity of the first incision, detach the tendon of the extensor carpi ulnaris from its groove on the lower part of the ulna, the ulnar artery and nerve being carefully avoided; divide the bone at the lower part of the middle third, and separate the lower and upper fragments from their articular connections as in the removal of these bones already described.

The *radius* and *ulna* may be removed together, and if the periosteum remains a useful limb may result. Make a straight incision the entire length of each bone on the dorsal surfaces, separate the muscles, and when the bone is reached raise the periosteum and detach the articular extremities; keep the limb well extended during the after-treatment.

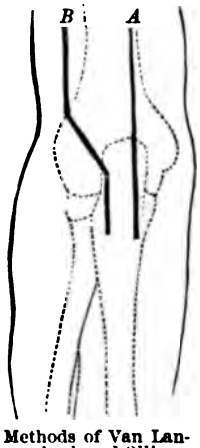
The *elbow-joint* has two motions, flexion and extension, which are limited to the locking of the coronoid and olecranon processes in the respective fossæ of the humerus. The usefulness of the joint after excision depends upon the perfection of the hinge- or antero-posterior motion. The extreme conditions in which it may be left are ankylosis and a flail-like or dangle-joint action. Though in both cases the limb is often very useful, yet every effort should be made to avoid such results. After-treatment has much to do with the prevention of ankylosis, but, in general, the extent of exsection determines the degree of mobility, and also the power of controlling it; if too little is taken away, there will be more or less complete ankylosis, and if too much, there will be such relaxation of the muscles as to prevent their efficient action: excisions which have given the best results have been at the commencement of the condyloid projections of the humerus and at the base of the coronoid

process of the ulna. The periosteum should be carefully preserved, whatever method is adopted. It may be established as a rule that excision for injury should be partial and conservative, and for disease it should be entire or limited only by the removal of the diseased bone. When the disease or injury is limited, it is of doubtful propriety to inflict additional injury by section of healthy bones, for excellent results have been obtained when the joint-ends of either the upper or forearm have been removed after complete exposure of the joint and the uninjured portions of the articulation have been unmolested. In general, the longitudinal incision, by giving sufficient exposure of the joint and enabling the operator to avoid easily the transverse division of muscular attachments, ligaments, and fibrous structures, should be preferred. The subperiosteal method gives the best results as to the usefulness of the limb, and should be performed unless the conditions require the sacrifice of these tissues. Subperiosteal exsection is as follows: Make an incision, *A* (Fig. 296), three inches long on the posterior surface of the joint, a little internal to the middle of the olecranon, beginning about an inch above the tip of the olecranon, and extending an inch and a half or two inches above that point, upon the border of the ulna, and through muscle, tendon, and periosteum to the bone; with the elevator raise the periosteum of the ulna toward the inner side, and detach the inner half of the tendon of the triceps in connection with the periosteum by means of short, parallel, longitudinal incisions; with the left thumb-nail draw the soft parts which cover the internal condyle and enclose the ulnar nerve toward the epicondyle, and detach them by means of curved incisions until the epicondyle is entirely uncovered; the last incisions separate the origins of the flexor muscles and the internal lateral ligament, their connections with the periosteum being retained; now draw the outer portion of the triceps tendon outward and separate it by short incisions from the olecranon, maintaining, however, its connections with the periosteum of the outer side of the ulna, which is raised from the bone with the insertions of the anconeus; by repeated incisions along the bone loosen the fibrous capsule of the joint from the margin of the humerus, first over the trochlea, until the internal condyle appears; detach the external lateral ligament and origins of the extensor muscles, so that all remain in connection with each other and the periosteum; now forcibly flex the arm, protrude the articular surfaces through the wound, and saw them off; if the ulna is sawn off below the coronoid process, separate the upper fasciculi of the brachialis anticus without disturbing the union of the tendon with the periosteum. Subperiosteal resection may be so performed as to retain the origins of muscles as follows: Make parallel incisions of proper length over the external and internal condyles; raise the soft parts from the internal condyle, separate the attachments of the flexors with lamellæ of bone by means of a chisel; raise the periosteum on both surfaces with the elevator, and divide the lateral ligament; repeat the same operation on the external condyle; now divide the humerus above the condyles; separate the attachments of the triceps with the periosteum and lamellæ of bone; detach the coronoid process from the ulna; divide the extremity of the ulna and remove it.

Other incisions may be made as follows: Fig. 296, *B*, Ollier; Fig. 297, *A*, Nélaton, *B*, *C*, Hüter.

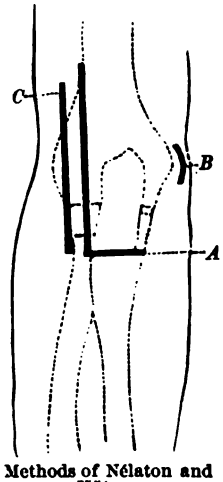
An osteoplastic operation may be performed as follows (*A*, Fig. 298): Make an incision from the end of the external condyle across the olecra-

Fig. 296.



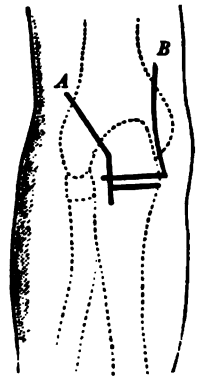
Methods of Van Langenbeck and Ollier.

Fig. 297.



Methods of Nélaton and Hüter.

Fig. 298.

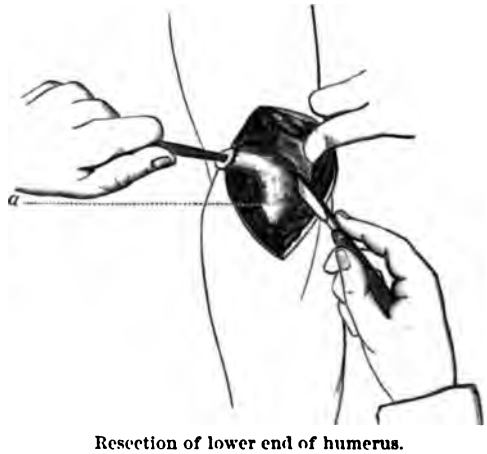


Osteoplastic method: *A*, Von Mosetig-Moorhof; *B*, by external incision.

non, then upward along the olecranon to a point an inch above its end; draw aside the ulnar nerve and divide the olecranon; now expose the humerus and saw it off below the epicondyles; remove the head of the radius and reunite the olecranon with wire. An external incision, *B*, can be adopted.

The *humerus* is generally resected in part, though it has been re-

Fig. 299.



Resection of lower end of humerus.

moved entire. (*a*) The lower extremity of the humerus is resected as follows: Make a straight incision on the posterior and external part of

the arm (Fig. 299) sufficiently extensive to give a free exposure of the bone, *a*, when the wound is separated; denude the bone and divide with the chain saw; raise the cut end, and proceed to disarticulate with the point of the knife, carefully avoiding the brachial artery in front and the ulnar nerve behind and at the inside.

(*b*) Resection of the shaft requires the utmost care to avoid wounding the brachial artery, which, with the median and ulnar nerves, passes along the posterior margin of the biceps muscle, and the superior profunda artery and musculo-spiral nerve, which wind around the posterior and external part of the upper and middle portions of the shaft. If the upper portion of the shaft is to be removed, make a straight incision on the external part of the deltoid muscle, care being taken not to extend the incision upward so as to involve the circumflex artery and nerve; when the lower part of the shaft is excised, the incision should be along the outer border of the brachialis anticus muscle, avoiding the musculo-spiral and external cutaneous nerves; the bone is readily exposed and removed to the required extent.

(*c*) The upper extremity consists of the head surrounded by the capsular ligament, the tuberosities, and shaft. Resect thus: Make a straight incision, commencing a little above and outside of the coracoid process and half an inch below the clavicle, and carry it downward to the requisite extent along the deltoid muscle on the anterior part of the joint; the bone is here quite superficial, and is most readily exposed; the bicipital groove being found, dislodge the long head of the biceps muscle and draw it aside (Fig. 300, *b*); divide the tendons of the sub-

FIG. 300.

Resection of upper end of humerus.

scapularis, supra- and infra-spinatus, and teres minor as they are made tense by rotation of the bone outward and inward; open the capsule and resect.

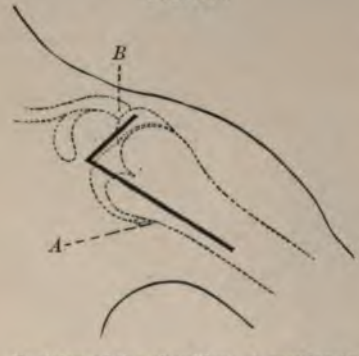
(*d*) The entire humerus may be extirpated: the thickened periosteum must be left in the wound, and the length of the limb preserved in order to aid the formation of new bone, on which the usefulness of the extremity will depend. If no new bone forms, the patient may have a useful arm supported by a ball-and-socket apparatus from the shoulder. The in-

cision must be the same as for the resection of the upper and lower extremities, avoiding carefully the musculo-spiral nerve.

The *shoulder-joint* consists of the large and hemispherical head of the humerus, opposed to the much smaller surface of the glenoid cavity of the scapula; the ligaments are the capsular, which invests the joint; the coraco-humeral, a broad bundle of fibres extending over the upper and outer part and attached to the root of the coracoid process; and the glenoid, which surrounds and deepens the articulation. The method of operation has a marked relation to the usefulness of the limb; *e. g.* the longitudinal incision gives 8 per cent. perfect and 45.6 per cent. useful limbs; the various other incisions give but a fraction over 1 per cent. perfect, and at the highest 11 per cent. useful limbs. The straight incision should, therefore, be preferred in ordinary excisions. Subperiosteal excision of the humerus should, as far as possible, be practised in order to secure greater length of limb, for while the degree of shortening ordinarily bears a certain relation to the extent of bone excised, in subperiosteal exsections this law does not hold good, the shortening being comparatively vastly less in the latter; *e. g.* 3.93 inches removed with periosteum gave 3 inches shortening, while 4 inches removed subperiosteal gave only ½ an inch shortening.

Exsection may be performed by the methods already given (Fig. 300), or as follows: The patient lying on the back, the shoulder raised on a cushion, and the external condyle looking forward, make an incision, *A* (Fig. 301), from the acromion directly downward through the deltoid muscle to the capsule and periosteum; draw aside the margins of the wound with retractors and recognize the tendon of the long head of the biceps; run the point of the knife along the outside of the tendon, opening the groove and capsule to the acromion; draw the tendon to one side, and, while the arm is rotated outward, with a circular sweep of the knife, held perpendicularly to the bone, divide the capsule and the attachment of the subscapularis to the lesser tuberosity; then rotate the arm inward, and in the same manner sever the capsule and the insertions of the supra- and infra-spinatus and teres minor from the greater tuberosity: the head of the bone is now thrust out of the wound and removed by a narrow back saw passed behind it. Any portion of the glenoid cavity may be exsected through this wound. If larger space is required, an additional incision may be such as to completely expose the joint and parts adjacent, *B* (Fig. 301). Subperiosteal resection may be effected by this method as follows: Divide the periosteum along the incision and raise it from the bone, first on the inside while the arm is rotated outward, detaching with it the insertions of the subscapularis; then on the outside while the arm is rotated inward, separating the insertions of the external rotators; this part of the operation is difficult in primary resection owing to the thinness of the periosteum;

FIG. 301.



Excision of the shoulder: *A*, regular incision; *B*, supplementary.

the head of the bone being now exposed, it may be turned out and excised.

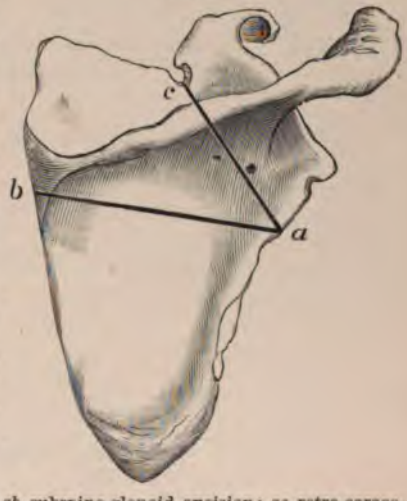
The **treatment** consists in fixing the arm upon the triangular cushion, and applying iodoform dressings and inserting a suitable drainage-tube; in primary exsection the tube may pass out of an opening made posteriorly, the wound itself being firmly closed by sutures.

The *scapula*, in part or in whole, has been resected for shot injuries, necrosis, and morbid growths. For shot injuries it is sometimes necessary to excise undetached portions of bone to facilitate the extraction of foreign bodies, and when there is great comminution it may be advisable to excise considerable portions of bone; there may be conditions also resulting from lacerations by large projectiles which would render primary extirpation of the scapula advisable; but, as a rule, it is better, after removing detached fragments, to wait the efforts of nature to consolidate the fractured bone, and to resort to resection as an intermediary or secondary measure in cases of extended necrosis. Extirpations of the entire scapula for morbid growths have proved so successful as to render it a legitimate operation.

(*a*) The body may be removed to a greater or less extent, as follows: Make three incisions, one along the spine and the other two from its extremity, one upward and the other downward; dissect flaps from the supra- and infra-spinatus fossæ, saw through the root of the acromion, and denude the anterior and posterior surfaces of the bone; reverse the body of the scapula from within outward, and divide the part at the proper point with the saw. Or make a longitudinal incision extending from the superior to the inferior angle along the vertebral border, a second parallel incision extending from the neck of the acromion to the middle of the anterior border; a transverse incision unites these along the spine; dissect the flaps, detach the muscles posteriorly and anteriorly, and divide the bone with the chain saw or forceps.

(*b*) The spine may be resected by an incision made parallel to its border; if required, the incision may be curved downward, so as to raise a flap; the bone being denuded, the diseased portions may be removed with a strong cutting forceps. To resect the acromion make a semilunar incision at the posterior part of the shoulder with the convexity downward; pass the chain saw under the narrow part of the neck of the acromion, divide the bone at this part, and disarticulate; or make a crucial or T-incision. An angle of the scapula may be resected by a transverse, or a V, or a crucial incision over the part.

FIG. 302.



ab, subspino-glenoid excision; *ac*, retro-coraco-glenoid excision (Chalot).

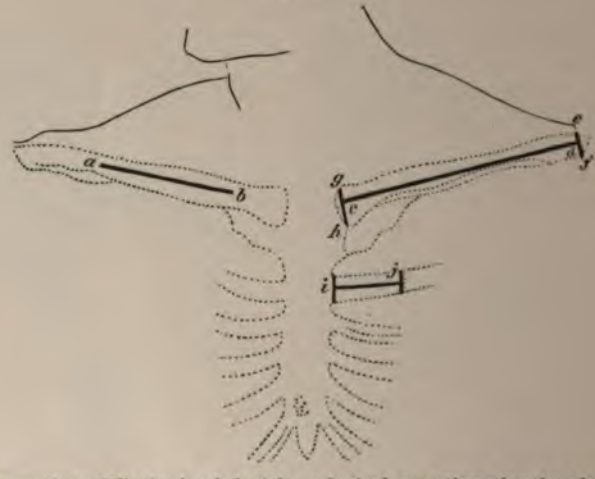
(*c*) Chalot describes a subspino-glenoid and a retro-coraco-glenoid excision by the lines of incision shown in Fig. 302.

(*d*) The entire scapula is removed by an incision from the acromion process to the posterior edge of the scapula, and another from the centre of this one downward; reflect the flaps thus formed, separate the scapular attachment of the deltoid, and divide the connections of the acromial extremity of the clavicle; to command the subscapular artery divide and tie it without delay; next cut into the joint and around the glenoid cavity, hook the finger under the coracoid process, so as to facilitate the division of its muscular and ligamentous attachments; then, pulling back the bone forcibly with the left hand, separate its remaining attachments with rapid sweeps of the knife.

The *clavicle* has such immediate relations to the upper walls of the thoracic cavity that operations for its extirpation must be cautiously performed. In shot fractures, detached splinters should always be immediately extracted; necrosed bone should be cautiously removed, in order not to injure neighboring parts; the removal of morbid growths involving the clavicle may prove to be a most serious operation.

(*a*) The scapular extremity is broad and flat, and is removed by a curved incision with its convexity forward and a little outward, which, reflected backward, completely exposes the bone. For a tumor make a crucial incision through the integuments and the platysma myoides, one limb nearly in a line with the clavicle and the other at right angles, and dissect the flaps and fascial coverings successively down to the external basis of the tumor; carefully detach the pectoralis and deltoid muscles from their clavicular origin, avoiding the cephalic vein, and divide on a director the fibres of the trapezius and the cleido-mastoid muscles. Dis-

FIG. 303.



a b, resection of diaphysis of clavicle; *c d e f g h*, resection of entire clavicle; *i j*, total resection of cartilage of rib.

articulate the scapular extremity of the bone, and the mobility thus communicated to the mass facilitates the completion of the operation.

(*b*) The entire clavicle may be resected by an incision parallel to its inferior border extending to or a little beyond its extremities; add two

vertical incisions, of one to two inches in length, at the ends of the first incision; the flap resulting from which divisions, on being raised up, completely lays bare the bone (Fig. 303). For a tumor make an incision from the acromial extremity of the clavicle to the sternal extremity of the clavicle of the opposite side; cross this by an incision at right angles with it in the middle of the clavicle; dissect the four flaps from the surface of the tumor; detach the deltoid from its anterior and the trapezius from its posterior edge, and divide the coraco-clavicular ligament; pass the chain saw and divide the bone; seize the fragment with the forceps, and detach the soft parts with the point of the knife, the edge being kept constantly turned toward the bone, in order not to make the slightest wound of the soft parts.

(*c*) The sternal extremity is of a triangular form, and has on its postero-superior surface the sterno-mastoid and sterno-hyoid muscles, on its anterior surface the pectoralis major muscle; posteriorly it is in near relation with the pleura, internal mammary artery, subclavian vein, and transverse cervical artery; the innominata is on the right and the thoracic duct on the left side. Resect as follows: Make (Fig. 304) an incision curved downward, the degree of the curvature depending upon the size of the bone, but always so arranged as to enable the operator to raise it by dissection to the upper part; after raising the flap, instead of separating the muscles, pass a chain saw at the point where the bone is to be divided; remove the fragment by carefully disarticulating it with the point of the knife, and avoid wounding the important parts posteriorly.

FIG. 304.

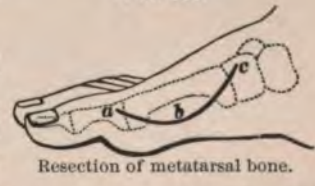
Resection of sternal end of clavicle.

BONES AND JOINTS OF THE LOWER EXTREMITIES.

The lower limbs are employed in support and progression, and hence resections should be so performed as to preserve the utmost stability.

The *phalanges* of the toes and their joints may be resected by the methods given for the corresponding bones of the fingers. The great toe is of the utmost value in progression, and in removing diseased bone from any part of it every effort must be made to retain periosteum, with a view to the preservation of its function.

FIG. 305.



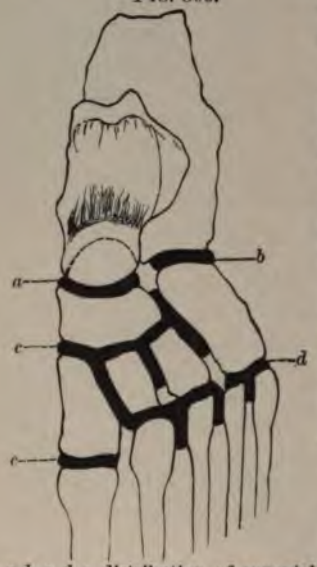
Resection of metatarsal bone.

The *metatarsal bones*, like the metacarpal, may be partially or entirely removed, and by similar methods. The resection of the entire first and fifth metatarsal bones requires a curved incision with its convexity downward, *a*, *b*, *c* (Fig. 305), and extending beyond the articulation; the bone being exposed, the middle of the shaft should be divided with the saw and the fragments separately disarticulated. In the removal

of the three middle metatarsal bones a long straight incision should be made, the bone divided in its centre, and the operation completed as in the preceding case.

The *metatarso-tarsal joints* are exsected by a semilunar incision on the dorsum of the foot, exposing the first row of tarsal bones. Remove their surfaces with a saw; now expose the articular surfaces of the metacarpal bones and excise them.

FIG. 306.



a, *b*, *c*, *d*, *e*, distribution of synovial membranes.

The *tarsal bones* may require removal singly or in groups. These operations have never been performed according to any prescribed rules, but each operator has adapted his incisions to the exigencies of the individual operation. In many cases the bones have not been resected entire, but the portion of bone diseased has been removed with a gouge. Care should be taken not to involve the synovial membrane of adjacent articulations which do not communicate with the point involved (Fig. 306), and, whenever practicable the periosteum should be preserved. The astragalus and os calcis require special notice.

The *astragalus* has most important connections: above it articulates with the tibia, laterally with the malleoli, and below with the calcaneum by two surfaces. It is attached to the calcaneum by the interosseous, posterior, and external ligaments, and to the scaphoid by a ligament passing from its anterior extremity. Excision may be made with slight injury to the tendons which pass over that region or by their destruction. The

FIG. 307.

A, excision of astragalus (inner incision); *A*, excision of ankle (inner incision).

former methods are very tedious, but give the best results. Excision is as follows: Make an external incision two and a half inches in length, *A* (Fig. 308), from the lower extremity of the tibia and anterior to the

external malleolus, to the middle of the cuboid bone, and a second incision backward from the centre of this incision just under the mal-

FIG. 308.

A, excision of astragalus (outer incision); *B*, excision of ankle (outer incision); *C*, excision of os calcis.

leolus; the bone is thus exposed between the peroneus brevis and tertius; all its connections should be divided. Make an internal incision two inches long, *A* (Fig. 308), from just below the tip of the inner malleolus, in a curved direction, along its anterior margin, forward and upward; separate all ligaments; seize the bone with strong forceps and withdraw it, dividing any remaining attachments.

FIG. 309.

Excision of the os calcis.

The *os calcis* articulates above with the astragalus by two articular surfaces having an interosseous ligament; in front with the cuboid, to which it is firmly bound by four ligaments, two plantar, which are very strong, a dorsal and an interosseous. Resection by the plantar flap (Fig. 309) gives ready access to the bone and removes the cicatrix from the plantar surface. The patient lying upon his face, make a horseshoe incision; carry it from a little in front of the calcaneo-cuboid articulation around the heel, along the sides of the foot to a corresponding point on the opposite side; dissect up the elliptic flap thus formed, the knife being carried close to the bone, and thus expose the whole under surface of the os calcis; then make a perpendicular incision about two inches in length behind the heel through the tendo Achillis, in the middle line and into the horizontal one; detach the tendon from its insertion and dissect up the two lateral flaps, the knife being kept close to the bones, from which the soft parts are well cleared; then carry the blade over the upper and posterior part of the os calcis,

open the articulation, divide the interosseous ligaments, and then by a few touches with the point detach the bone from its connections with the cuboid. Farabeuf has modified this method, *C* (Fig. 307, Treves), by making an incision from the base of the fifth metatarsal bone along the margin of the sole to a point one and a quarter inches to the inner side of the median line; another incision, two inches long, parallel to and a little in front of the tendo Achillis, joins the first. The flaps are raised from the bone, the periosteum cut vertically and raised from the bone, care being taken not to injure the peronei tendons in front. By careful dissection the bone is freed from its attachment and removed.

The *tarsal joints* generally become carious in connection with such extensive caries of the tarsal bones as necessitates the extirpation of entire bones. Single joints may be excised when the disease is limited, as the astragalo-scaphoid, *a* (Fig. 306), the calcaneo-scaphoid, the calcaneo-cuboid, *b*. The incision should be made over the affected joint and curved, and the articular surfaces should be removed with a fine saw or gouge.

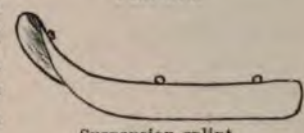
The *ankle-joint* is a hinge; the inferior extremities of the tibia and fibula united form a kind of arch which embraces transversely the superior articular surface of the astragalus so as to render lateral movements impossible when the ligaments are tense.

The operation which best preserves vessels, nerves, and tendons, as well as the periosteum, is by two longitudinal incisions, one over the external and the other over the internal malleolus, and extended above and below sufficiently to give free access to all of the diseased bone. All transverse incisions involving the vessels, nerves, and tendons should be avoided. The limb being turned on the inner side upon a firm pillow, make an incision two or three inches long *B* (Fig. 307) on the middle of the fibula down to the point of the malleolus, and sufficiently deep to divide the periosteum; from the extremity of the malleolus continue the incision backward, around the malleolus, an inch, merely through the skin, so as not to injure the tendons, and yet permit of their being raised from behind the malleolus; at the point where the bone is to be divided separate the periosteum with the raspatorium, and turn down as much as circumstances will permit; introduce the point of the index finger or a spatula into the interosseous space to protect the soft parts during the act of sawing; incline the saw slightly toward the joint, so that the part to be removed will be external at the point of division; seizing the upper extremity of the fragment with very strong forceps, separate its connections with the raspatorium and knife when necessary. Now turn the foot upon the external surface, and make the same straight incision as upon the fibula, and a transverse one at its lower end, *B* (Fig. 308); the periosteum is more easily separated than from the fibula; saw the tibia in place with a fine-bladed saw when the parts are unyielding from chronic inflammatory infiltration; in recent injuries and acute suppurations it may be possible, after the periosteum has been separated and the ligaments incised, to gradually dislocate the foot outward with the aid of the knife, and remove the tibia with the saw. To gain more complete access in many cases the incisions made along the centre of the malleoli may be extended laterally along the margins of the extremities of these bones. Or the same result may be attained by extending the

incisions made along the posterior margins of the tibia and fibula around the lower and anterior margins of the malleoli.

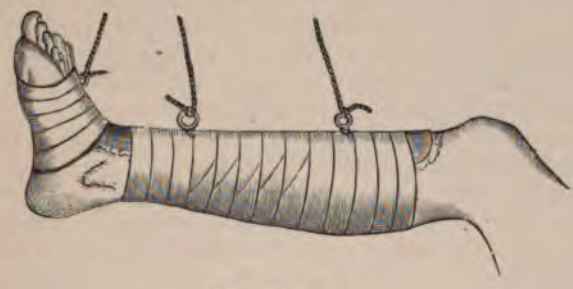
A convenient method of suspending the limb is as follows: Make a splint of wood or metal fitted to the anterior surface of the leg and ankle (Fig. 310), with rings inserted at three points for suspension; in its application the splint is well padded and laid on the front part of the leg and the limb fixed in the ordinary bandage, the ankle being free (Fig. 311); or the gypsum bandage may be applied over the splint and around the leg, a layer of old flannel being first adapted to the leg, and the ankle left exposed.

FIG. 310.



Suspension splint.

FIG. 311.



Leg suspended.

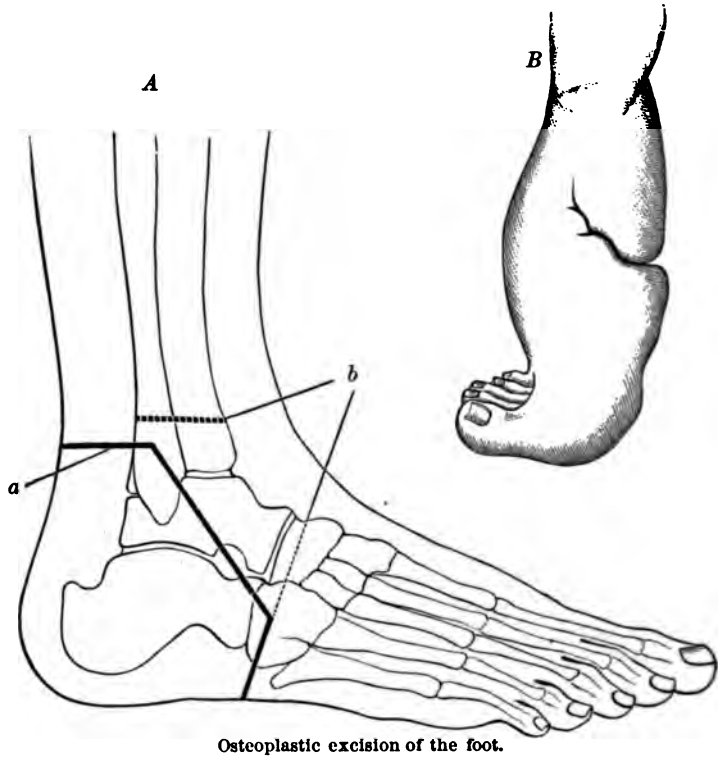
Osteoplastic excision of the ankle-joint (Mikulicz) (Fig. 312, *A*), is as follows: Place the patient in a prone position, and make the following incisions down to the bone: 1st, across the sole of the foot from a point a little in front of the tubercle of the scaphoid to a point just behind the tuberosity of the fifth metatarsal bone; 2d, from the extremities of this incision two incisions to the base of each malleolus; 3d, a transverse cut joining the ends of these incisions, *a;* 4th, then flex the foot, divide the lateral ligaments, and open the joint from behind, separate the os calcis and astragalus from their attachments, and remove them at the medio-tarsal articulations. Remove with the saw the extremities of the bones of the leg at the base of the malleoli, *b*, and the articular surfaces of the scaphoid and cuboid. Attach the incised bones of the tarsus to the cut surface of the tibia by wire, and apply the usual antiseptic dressings supported externally by gypsum bandages. The result is a talipes equinus (Fig. 312, *B*).

The *fibula* may be resected in whole or in part with the best results. No formal method is to be pursued. Make a straight incision over the part, uncover the bone, separate the periosteum, divide with a chain saw, and remove the fragments (Fig. 313).

The *tibia* is subjected to resection more frequently than any other long bone, owing to its subcutaneous situation. The results are most favorable, as new bone is readily reproduced when the periosteum is well preserved.

(*a*) The lower extremity forms the upper and internal part of the

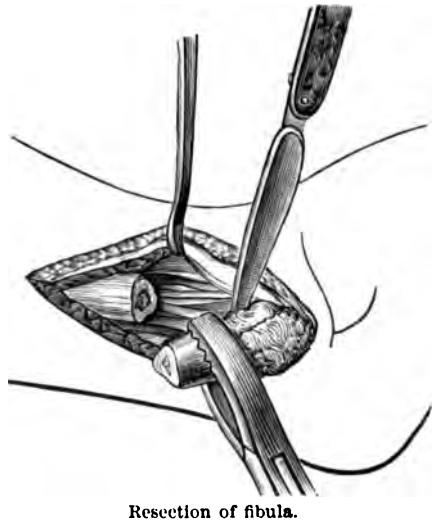
FIG. 312.



Osteoplastic excision of the foot.

ankle-joint; it is closely invested with tendons, and upon its postero-internal border the posterior tibial artery and nerve pass to the foot.

FIG. 313.



Resection of fibula.

Resection by the subperiosteal method of the entire diaphysis and lower epiphysis has resulted in reproduction of the bone removed and a useful limb. Make a straight incision along the crest to the ankle-joint; saw the bone at the requisite height; raise the bone from its periosteal bed by carefully separating the periosteum; dislodge the tendons from their grooves, divide the ligamentous structures, and complete the resection by detaching the bone from the articulation.

(*b*) The shaft of the tibia is subcutaneous on the anterior and inner part. On the posterior part it gives attachment to muscles, and along its external border is attached the interosseous ligament connecting it to the fibula. The operation will depend upon the extent of the disease and the location of the sinuses if the disease is necrosis. The incision should be along the subcutaneous borders of the bone, and extend beyond the diseased portion; the periosteum should be thoroughly separated from the shaft, and the bone divided with a chain-saw at either extremity; the fragment is then easily separated.

(*c*) The upper extremity of the tibia is broad, and presents upon its upper surface two cup-shaped cavities for articulation with the condyles of the femur. The operative process is entirely subordinated to the degree, actual situation, and form of the disease, so that there may be occasion for the crucial, the elliptical, or a simple incision, and also for a variety of saws and bone-cutting instruments. When practicable, subperiosteal resection should always be performed.

The *knee-joint* may be regarded as consisting of three articulations conjoined—namely, that between the patella and femur, and two others, one between each condyle of the femur and the tibia: the ligamentum mucosum is an indication of the original distinctness of the synovial membranes of the inner and outer joint; the crucial ligaments may be regarded as the external and internal lateral ligaments of those two joints respectively; each portion of the articular surface of the femur belongs either to one or other of the three component joints of the knee, and no part is common to any two of them. The knee is a hinge-joint, having free motion in but two directions; it is supported principally by the lateral, the internal, and the posterior ligaments, and in front by the patella and its ligamentous attachments; it has also a capsular ligament; the articular face of the tibia has a semilunar fibro-cartilage which deepens the articular surface for the condyles of the femur.

Present experience indicates that excision should be had recourse to whenever the injury or disease is of a nature to destroy the function of the joint and to require ankylosis to render the limb useful. It is generally undertaken for chronic affections which cause ulcerative processes within the joint. The antiseptic method has relieved the operation of all of its former dangers. It is no longer a question of age or sex, or even physical health, but the decision should rest entirely upon the determination of the nature of the disease and its final results upon the usefulness of the limb.

The following suggestions as to the extent of the excision are important: The patella should not be removed, unless diseased, as it is essential to the formation of a firm, well-applied flap; if carious, the diseased part may be removed with the gouge or forceps; in excision of the knee-joint in children remove at first a thin slice of bone, and, in case this

should not suffice, with the gouge scrape out carefully the softened and broken-down osseous tissue, leaving the much-thinned cortical substance, with the periosteum, behind; the epiphyseal cartilage is often by this means laid entirely bare from the side of the joint; if perforated with fistulous openings, a small spoon must be introduced and every particle of diseased tissue removed; in very young children it will often even not be necessary to remove any part of the tibia with the saw, it being practicable to remove the diseased part with the spoon; if the epiphyseal cartilage can be saved only in part, no more should be sacrificed than is actually necessary.

The method of operating will depend upon the kind of joint sought to be obtained: if union of the excised bones is necessary, the U-shaped incision is in general preferable to others, as it permits the removal of any necessary amount of bone without injuring the soft parts, and both corners of the wound are situated as low as the anatomical conditions will allow. If an attempt is made to retain motion, a lateral incision is to be preferred, which admits of exsection with the least destruction of the ligamentous tissues of the joint. The amount of bone removed must, of course, depend upon the extent of the disease.

Exsect as follows: The leg being slightly flexed on the thigh, make a curved incision, commencing at the insertion of the internal lateral ligament into the inner condyle of the femur, and, passing just below the lower extremity of the patella, terminate it at the same point on the external aspect of the joint; the lateral incisions should not be made lower than the insertion of the lateral ligaments, to avoid division of the articular arteries; reflect this flap upward (Fig. 314); remove the patella, if diseased; if not, leave it undisturbed and divide the lateral and inter-articular ligaments; pass a fold of antiseptic gauze through the joint,

FIG. 314.

Excision of knee.

FIG. 315.

Excision of the knee by the sawing of the tibia (Treves).

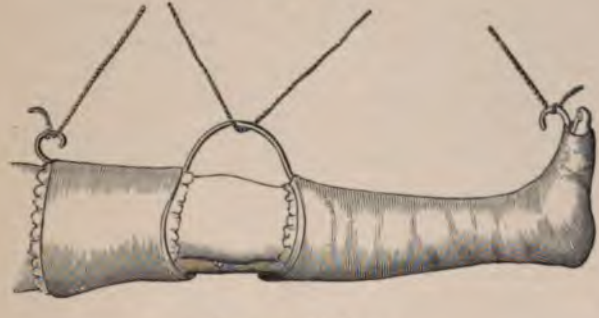
and draw it firmly under the extremity of the bone to be sawn, thus completely isolating the soft parts behind; apply the saw first to the extremity of the femur, and then to the articular head of the tibia.

The position of the saw should not deviate from a right angle to the shaft of the bones, so that when union takes place the limb will be nearly straight (Fig. 315). The bones must be maintained in apposition by two or three silver wires, which should now be introduced into the anterior part of the tibia and femur, and, when sufficiently twisted, cut off and the ends turned down between the bones. To fix the bones in position use has been made of nails, which are removed at the end of two or three weeks.

The dressings should be antiseptic—viz. layers of iodoform gauze next to the wound, then gauze bandages treated with bichloride solution, next borated cotton firmly bound by gauze bandages, and last a wire splint retained by gypsum bandages to immobilize parts above and below the knee. The knee itself should be so protected that it can be examined without disturbing the other dressings. The more superficial dressings should extend from the hip to the ankle. The limb should now be placed in a sling. The dressings should not be changed, except to remove the drainage-tube, for several weeks. The wires are allowed to remain, but nails must be withdrawn after several weeks.

The following dressing can be readily applied: Make a wooden concave splint to the calf of the leg and back of thigh, but narrow at the knee; also, if possible, an iron rod for suspension. Apply the dressing thus: Pad the posterior splint with lint or cotton-wool, and cover that part corresponding to the site of the wound with gutta-percha cloth or hot paraffin; place the limb in position and carefully adjust it; place

FIG. 316.



Suspension of leg.

the iron rod on the front and lay folded lint between it and the limb at the groin, at the upper part of the tibia, and at the bend of the ankle; apply an open woven roller bandage around the whole dressing from the toes upward except at the site of the wound; over this apply the gypsum bandage in two or three layers; when the dressing is firm suspend the limb by the hooks; the wounds may now be dressed without disturbing the part.

The *patella*, though in immediate relation with the knee-joint, may be excised with good results. Make a crucial incision, the transverse branch being over the base of the bone, or a second transverse incision may be made near the apex; dissect the flaps off cautiously, and remove

the bone or its fragments; the tendinous expansion surrounding the bone should be separated, and not divided, as far as possible. The antiseptic method should be strictly pursued, and the iodoform dressings applied. If the fragments of bone are not too much detached, they may be united with catgut sutures and union secured.

The *femur* is the largest bone of the skeleton. Resection of different portions of the bone are very frequent and give satisfactory results, especially when the periosteum is preserved, as new bone is reproduced. The lower extremity is rarely removed, except in exsections of the knee-joint. When it is necessary to operate for necrosis in this region the sinuses are the safest guides to the dead bone. The shaft of the femur gives attachment to muscles throughout nearly its entire extent, and to reach it without injury to the soft parts the muscular septa must be followed, either along the antero-external region of the limb or as indicated by the seat of the disease. The limb must be well supported by the firm gypsum dressing during the after-treatment. The trochanter major gives attachment to the gluteus medius and minimus, and by its fossa to the external rotators. In resection make a free crucial incision through the skin and tendon of the gluteus maximus, and when the surface is sufficiently exposed use the sharp spoon to remove diseased parts.

The *hip-joint* is a large ball-and-socket joint in which the globular head of the femur is received into the acetabulum or cotyloid cavity of the innominate bone: this articulating surface is deepened by a broad, ribbon-shaped cartilage occupying the upper and outer part and folded round a depression which, extending from the notch, is hollowed out in the bottom of the cavity, and is occupied by delicate adipose tissue covered with synovial membrane; the articulating surface of the femur presents a little beneath its centre a pit in which the round ligament is attached; movement is allowed in every direction, extension being limited by the anterior fibres of the capsular ligament, and flexion by the contact of the neck of the femur with the acetabulum. The extent of the resection should depend upon the amount of disease; if limited to the head, that part alone should be removed; if the neck is carious, the trochanter may still be preserved; but if the latter is involved, the bone must be divided at the trochanter minor.

The methods of operating are numerous, but the single incision, with subperiosteal removal of the bone, most nearly meets the anatomical indication of the part. Of the several arteries distributed to this region—namely, the gluteal, sciatic, obturator, external and internal circumflex, and the superior perforating by anastomosis—the only one which approaches the line of this incision near enough to be incised before dividing into branches of distribution too small to give rise to noticeable hemorrhage is a twig of the internal circumflex, which at one-eighth to one-fourth of an inch from the insertion of the obturator externus breaks up into its terminal divisions; this branch may be avoided by keeping the point of the knife well against the bone, and dividing the tendon of the obturator externus muscle in the digital fossa.

The patient lying on the sound side, with a strong knife commence an incision, *A* (Fig. 317), at a point midway between the anterior inferior spinous process of the ilium and the top of the great trochanter;

carry it in a curved line over the ilium in contact with the bone, across to the top of the great trochanter; extend it not directly over the centre

Fig. 317.

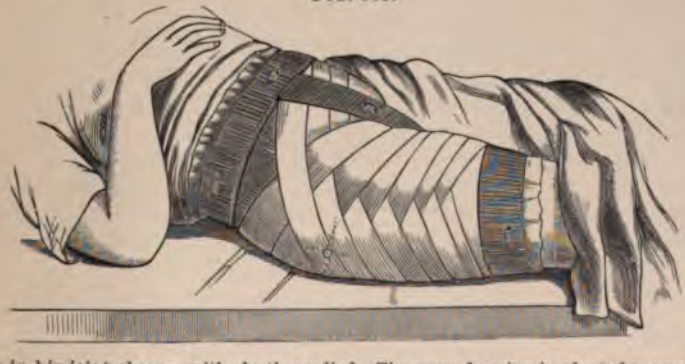
Excision of the hip; *A*, Sayre; *B*, Ollier.

Fig. 318.

Passing chain saw.

of the trochanter, but midway between the centre and its posterior border; complete it by carrying the knife forward and inward, making the whole length of the incision four to six or eight inches, according to the size of the thigh; if the periosteum has not been divided by the first incision, carry the point of the knife along the same line a second or third time; an assistant separating the wound with the fingers or retrac-

Fig. 319.



Dressing in hip-joint abscess, with elastic applied. The same dressing is adapted to excision; the position of the drain is seen (Cheyne).

tors, the great trochanter, *b* (Fig. 318), is exposed; with a narrow, thick knife make an incision through the periosteum only at right angles with

the first at a point an inch or an inch and a half below the top of the great trochanter, opposite or a little above the lesser trochanter, and extend it as far as possible around the bone, making sure that the periosteum is freely divided; at the junction of the two incisions of the periosteum introduce the blade of the periosteal elevator, and gradually peel up the periosteum from either side with its fibrous attachments until the digital fossa has been reached; with the point of the knife applied to the bone divide the attachments of the rotator muscle, and continue to elevate the periosteum, carefully avoiding rupturing it at any point; when the periosteum is removed as far as necessary, adduct the limb slightly, depress the lower end of the femur sufficient to allow the head of the bone to be lifted out only so far as is requisite to permit its removal with the saw, *g*; divide the bone just above the trochanter minor and remove the fragment; if the head of the bone cannot be raised before division on account of the involucrum, saw the bone first and then remove the head; if the shaft at the point of section is necrosed, expose and exsect more; examine the acetabulum, and if found diseased remove all dead bone; if perforated, the internal periosteum will be found peeled off, making a kind of cavity behind the acetabulum, and all diseased bone must be very carefully chipped off down to the point where the periosteum is reflected from sound bone. Every part of the wound and all sinuses must be thoroughly cleaned of particles of bone and false membrane. Or, make an incision, *B* (Fig. 317), commencing about three inches below the crest of the ilium, and at the same distance posterior to the anterior superior spine, downward to the trochanter major, and then along the centre of the shaft of the bone, and proceed as above.

FIG. 320.

Hip splint.

The dressings of the wound are as follows: Introduce the drainage-tube to the bottom, then pack the wound with iodoform gauze, or close the wound with sutures to the tube and apply iodoform-gauze pads. Envelop all with a wide and thick layer of borated cotton and apply the gauze bandage firmly. Place the patient on a smooth mattress and make extension at the foot with a six-pound weight. The upright position of the foot should be maintained, and the dressing should be changed as seldom as possible. When completed the dressings should envelop the upper part of the thigh, the hip, and pelvis (Fig. 319). The patient should not attempt to walk with crutches until the external wound is quite healed, which ordinarily occurs with antiseptic treatment in five or six weeks. Attempts to bear weight on the foot should not be encouraged for six months, in order to allow the fibrous structures to consolidate. During the period between the healing and using the limb the hip splint (Fig. 320) should be worn.

With children, extension by the application of weights and proper positions of the limb is the best means: the patient may be placed on a divided mattress, of which the two different parts are separated

by an interstice of several inches exactly corresponding to the spot where the excision was made.

BONES OF THE TRUNK.

The *vertebræ* have been subjected to frequent partial resections. The removal of loose fragments after severe injuries, as from shot, is perfectly rational, and has resulted in a fair measure of success. In the removal of a spinous process or arch make a long incision above the ridge of the spinous process, the middle of which is opposite the displacement; divide all the attachments of the muscles to the articular processes; as one end of each muscular bundle is separated from its attachment, it retracts and needs little holding back; the saw or the nippers are generally sufficient to divide the vertebral arch; in sawing or cutting out the arch grasp the spinous process, if it be not broken, with a pair of stout tooth forceps, which are to be preferred to the elevator for lifting the detached bone from its natural connections; a small crowned trephine may be used to cut through the vertebral arch, or Hey's saw.

The *coccyx* may be excised in whole or part for necrosis, fracture, or for a painful affection, coccydynia, thus: Place the patient on the side, the thighs flexed, and the hips close to the edge of the bed; the buttocks being separated, make an incision in the median line extending from the extremity of the coccyx upward to the requisite extent; remove the diseased bone either with the gouge or the drill, or the bone may be divided with the cutting forceps. The fore finger in the rectum determines the progress and extent of the resection.

The *ribs* are closely invested on their internal surface by the pleura, and along the groove on the lower border runs the intercostal artery. The only admissible primary interference when the ribs are fractured by balls is the extraction of loose fragments and the smoothing off of sharp-pointed ends. Resection for necrosis should be made by opening existing sinuses and carefully separating the thickened periosteum with the pleura. In the removal of morbid growths portions of ribs may require resection; great care must be taken to separate the pleura with the periosteum without wounding the former. Proceed as follows: Place the patient upon the sound side, and expose the bone by an incision along the middle of the rib, or the incision may be curved downward: divide the intercostal muscles and disengage the intercostal artery from its groove in the inferior border of the bone; separate the pleura cautiously with the handle of the scalpel or similar instrument, and pass a thin piece of antiseptic pasteboard or other substance behind; divide the bone with the chain saw. Section of the posterior part of the rib may be first made to avoid wounding the pleura; scrape carefully each border of the bone, and do not incline the point of the knife toward the intercostal space. In removing the false ribs support the free extremity while the rib is divided posteriorly. The *costal cartilage* may be removed by an incision along its centre and vertical incisions at each extremity.

The *sternum* has been frequently partially resected for shot injuries, and with very favorable results, the mortality being very slight. When subperiosteal resection has been made for necrosis new bone has been reproduced. The incision for resection may be crucial or vertical, accord-

ing to the extent of injury or disease, and the parts may be removed by the trephine, gouge, or forceps. The upper portion may be removed by a vertical incision, with transverse incisions at each extremity. The bone is divided with a saw, and the costal cartilages with a strong scalpel from before backward (Fig. 321).

FIG. 321.

Incision for resection of upper part of sternum.

BONES OF THE FACE.

In resection operations on the bones of the face it is important to avoid, as far as possible, incisions which will leave unsightly scars and the removal of bones which destroy the symmetry of the features. When practicable, perform intrabuccal resections without external incision; make incisions along the natural folds of skin and preserve borders of the mouth from division; in all cases that admit of subperiosteal resection this method is to be preferred.

The *inferior maxilla* is very liable to injury and necrosis and to be the seat of morbid growths. In comminuted fractures the fragments should be preserved unless quite detached, as they have great vitality and are important in the preservation of the contour of the jaw. For necrosis the resection should as far as possible be subperiosteal and intrabuccal, and both objects may often be accomplished by occasionally aiding the slow process of separation of the necrotic bone from its attachments to bone and periosteum with the elevator or the handle of the scalpel or a spatula. By degrees the sequestrum is loosened, new bone forms around it from the periosteum, and eventually the dead bone may be lifted from its bed with perhaps slight incisions of the gum; by this method large portions of the jaw, and even the entire jaw, may be reproduced during the process of sequestration, and not only its contour, but its function, be preserved. This method is preferable to early resection, which is liable to be followed by great contraction of the parts, even if the periosteum is preserved and new bone is produced. In resection for tumors ample external incisions are often required, and large portions of the bone must be sacrificed. But small tumors, involving only the alveolus, may be removed with bone forceps without incision of the skin. A considerable portion of the central part of the jaw may be removed without incising the lip if the mucous membrane is freely divided between it and the bone and the lip is drawn well down. The wound must be disinfected with a weak bichloride solution, 1 : 5000, care being taken to prevent its entering the stomach. In closing these wounds endeavor to unite first the cut surfaces of the mucous membrane by sutures so applied as to cause slight eversion of the free margins into the mouth. Then accurately close the external wound, using catgut drains, and apply iodoform dressings.

(*a*) When the central part is to be resected proceed as follows: Pass a stout ligature through the tip of the tongue to hold it in position when

the muscles are incised; an assistant, standing behind the patient, holds his head firmly and compresses the two facial arteries at the points where they cross the lower jaw. Standing in front, seize with the left hand one of the angles of the lower lip, while an assistant holds the other angle from the bone and the whole in a state of tension; divide the lip with a vertical incision through the median line down to the os hyoides, thus making flaps.

FIG. 322.

AB, incision for resection of the middle part of the body of the lower jaw (Chalot).

Or make a single curved incision along the lower margin of the jaw; raise the periosteum from the bone to be removed; extract a tooth opposite to each point where bone is to be sawn through; use a small Hey's saw or the chain saw; the bone being sawn through on both sides, divide the muscles attached to it as closely as possible to their insertion, carrying the knife along the concave surface (Fig. 322). Unite the two flaps with silver-wire sutures passed through to the mucous membrane, adjusting the margins of the lip; or use the hare-lip pins with figure-of-8 suture if there is much tension; attach the ligature holding the tongue to a fold of adhesive strip firmly fastened.

(*b*) The horizontal portion has the following anatomical parts to be considered: Attached on its internal surface is the mylo-hyoideus muscle, beneath which is the fossa for the submaxillary gland; on its external surface along its lower margin is the attachment of the platysma myoides muscle, and along its alveolar margin the buccinator; the facial artery mounts over its lower border just anterior to the insertion of the masseter muscle. Resect as follows: Make an incision commencing behind and a little above the angle, avoiding the facial nerve and parotid duct along the border of the jaw, terminating from a quarter to half an inch below the symphysis menti; raise and reflect the flap on the face, tying both ends of the divided facial artery; the bone being denuded or the periosteum raised, divide with a chain saw passed at the proper point anteriorly, a tooth being removed if necessary; seize the end of the fragment with strong forceps, and divide with the chain saw at or near the angle, as may be required; close the wound firmly, care being taken to compress the surfaces of the incised mucous membrane closely to secure prompt union.

(*c*) The half of the lower jaw has the following additional relations: The ramus terminates in two processes, one for articulation and the other to give attachment to the temporal muscles; the articulation is supported by an external and internal lateral and the capsular ligament; the stylo-maxillary passes from the styloid process to the angle of the jaw; the internal maxillary artery passes behind the neck of the condyle in such proximity as to render care necessary to avoid wounding it in disartic-

ulation of the jaw. Resect as follows (Fig. 323): Place the patient with the shoulders raised and head turned to the opposite side; commence the incision at the zygomatic arch behind the condyle, carry it downward behind the ramus to the angle and under the body of the bone to a point

FIG. 323.

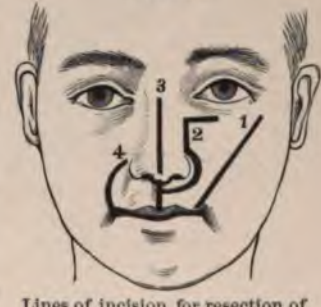
Excision of half of lower jaw.

one-quarter of an inch below the symphysis menti if the operation is for an old necrosis, but through the centre of the lip if for the removal of bone for other affections: in the former case incise the periosteum and raise it from the bone throughout, but otherwise, for the removal of a tumor, the facial artery must be cautiously divided and secured. Subperiosteal resection may now be rapidly performed for necrosis, the bone being divided with the chain or small straight back saw, and the cut end used as a lever to raise it from its position during the process of enucleation. If the periosteum is not saved, having divided the bone, seize the cut extremity with the hand; raise it from its bed, carefully separating all tissues adherent to the body and ramus; carry a narrow-bladed knife or curved scissors beneath the zygomatic arch and behind the coronoid process, and with it divide the tendon of the temporal muscle while depressing the bone to disengage the process and luxate the condyle; pull the bone strongly outward, as far as possible from the vessels, in order to avoid especially the internal maxillary artery, and complete the operation by dividing the pterygoid muscles and the articular ligaments. Secure every bleeding vessel and close the wound by carefully adjusting the margins of the integument and of the mucous membrane. When the tumor is large and completely wedged in the upper part of the bone, so as to hinder the freeing of the coronoid process and prevent dislocation, cut off the tumor as high as possible with the bone forceps or saw, and

then remove the remaining portion of the jaw only in case the disease is malignant.

(*d*) The entire lower jaw is removed as follows: Pass a ligature through the anterior part of the tongue, and trust it to an assistant; make an incision commencing opposite the left condyle downward toward the angle of the jaw, ranging at about two lines in front of the posterior border of the ramus, thence along the base, to terminate at the median line a little posterior to the most prominent part of the border of the jaw. Dissect upward the tissues of the cheek, and reflect downward, for a short distance, the lower edge of the incision; separate the tissues forming the floor of the mouth, situated upon the inner surface of the body of the bone, from their attachments from a point near the median line as far back as the angle of the jaw; next divide the attachments of the buccinator; secure by ligature the facial artery, the submental and the sublingual; expose the external surface of one branch of the jaw and of the temporo-maxillary articulation by dissecting the masseter upward as far as the zygomatic arch; seize the ramus and pull the coronoid process downward below the zygoma; divide the insertion of the pterygoideus internus, grazing the bone in doing so; carefully avoid the lingual nerve, here in close proximity; divide the dental artery and nerve; separate the tissues attached to the inner face of the bone as high up as a point situated about a line below the sigmoid notch, between the condyle and the coronoid process; detach the tendon of the temporal muscle by means of blunt curved scissors or a probe-pointed bistoury, keeping close to the bone; make use of the ramus, now movable, as a lever to aid in the disarticulation of the bone: to effect safely the disarticulation of the condyle, penetrate the joint by cutting the ligaments before backward and from without inward; the articulation thus opens sufficiently to allow the condyle to be completely luxated; blunt scissors may now be used to cut carefully the internal part of the capsule and the maxillary insertion of the external pterygoid muscle; by a slow movement of rotation of the ramus upon its axis the condyle is detached and the operation completed. To effect the removal of the other half make the same incision on the opposite side, so as to meet the first on the median line; the dissection is similar.

FIG. 324.



Lines of incision for resection of upper jaw.

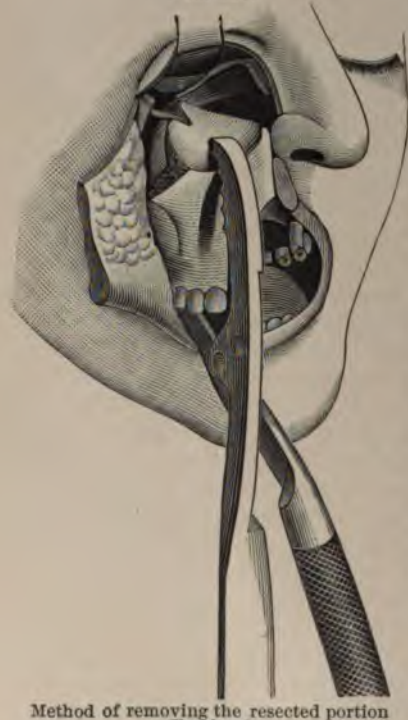
The *superior maxilla* has the following important anatomical features: It is attached to other bones at but three principal points: First, by its ascending process and articulations with the os unguis and ethmoid; second, by the orbital border of the malar as far as the spheno-maxillary fissure; third, by the articulation of the two maxillary bones with each other and the palate-bone; there is a fourth point of contact behind with the pterygoid process and the palate-bone, which yields easily by simple depression of the maxillary bone into the interior of the mouth: in attacking these different points no large vessel is injured; the trunk of the internal maxillary artery may be easily avoided, or in any case tied after the

removal of the bone; moreover, in case of unforeseen hemorrhage during the operation we have a resource in compression of the carotid; only one important nerve-trunk, the superior maxillary, need be divided.

Resection of the bone is performed for the extirpation of malignant growths and to gain access to naso-pharyngeal tumors: in the former case it is justifiable only where the disease is limited to the upper jaw and its corresponding palate-bone, owing to the certainty of recurrence if the disease extends beyond. The methods of procedure are numerous, and give great and desirable latitude to the operator. Early operators cut boldly through the cheek, 1 (Fig. 324), but to avoid unsightly scars the rule now obtains of making the incision in the course of natural folds of the skin, 2 and 4 (Fig. 324). Subperiosteal resection may be made by these incisions, but a more formal operation is made by following the line 1 (Fig. 324).

Resect the superior maxilla below the floor of the orbit by the following operation (Guérin): Make an incision slightly convex backward, commencing at the ala of the nose and terminating at the corresponding commissure of the lip, following the naso-labial fold or furrow, 4 (Fig. 324); dissect up the two flaps resulting from this incision until the nostril is exposed and the malar process is completely denuded; with a small saw held in the right hand, saw through the malar process from above downward, and a little from within outward; the soft palate having been detached from the posterior border of the palatine bone by a transverse incision made at the posterior border of the last great molar, and an incisor tooth having been extracted, divide the horizontal portion of the maxilla from before backward with cutting forceps, one branch being in the mouth, and the other in the nares; make a section of the bone from the divided malar process to the nares by the forceps; seize the bone with strong forceps, and remove, fracturing the pterygoid process (Fig. 325). After thorough disinfection of the wound apply iodoform dressings.

FIG. 325.



Method of removing the resected portion (Farabeuf).

The entire maxilla or portions may be resected as follows: Extract the incisor teeth of that side; divide the upper lip in the median line to the nostril; continue the incision around the ala and up the side of the nose toward the inner canthus of the eye, thence continue it in a slight curve below the orbit, 2 (Fig. 324), or to the malar bone; reflect the skin from the bone, and with a narrow saw passed into the nostril

divide the alveolus and hard palate; incise the mucous membrane of the mouth as far back as the soft palate; cut partially also the malar process of the maxillary bone, or, if necessary, the bone itself, and the nasal process of the superior maxilla, and complete the division of these bones with the forceps; grasp the bone with the lion forceps and detach it forcibly from the pterygoid process and palate-bone; when the bone is loose raise the fascia of the orbital palate, separate the infra-orbital nerve, the soft palate, and any adhering tissues. The hemorrhage must be suppressed by ligatures and the actual cautery, and the wound adjusted at the lips by hare-lip pins and in other parts by carbolized silk sutures.

The *superior maxillæ* may be removed at a single operation by an incision, 3 (Fig. 324), along the centre of the nose and through the upper lip; additional incisions may be made, if required, under the orbit laterally. Or, a four-cornered flap may be made by an incision on either side from the angles of the mouth to the external angles of the eye, 1 (Fig. 324). The divisions of the bone by the different operations are instructively shown by Treves.

FIG. 326.

Saw incisions in the maxillæ: *A, B, C,* excision of the upper jaw; *D,* Boeckel's operation (nasal polypus); *E, C,* Guérin's operation (partial excision); *F, F,* Langenbeck's operation (nasal polypus); *G,* excision of lower jaw; *H,* removal of portion of alveolus; *I,* Esmarch's operation (ankylosis of jaw) (Treves).

THE EXTREMITIES.

AMPUTATION.

An amputation is required only when the question of recovery by other means is negatived beyond all reasonable doubt, or when the presence of

an incurable disease is a source of such evil or discomfort as to render the loss of the limb desirable or beneficial to the patient. The final judgment as to the necessity of an amputation in any given case must be sustained by the latest surgical experience, for an amputation that would formerly have been justified would now be repudiated by the best authorities, and the operator justly charged with ignorance and unskilfulness.

FIG. 327.

Antiseptic knives, hard-rubber handles.

The *instruments* required to form a complete amputating case are a long and short knife and catling (Fig. 327), metacarpal saw, scalpel, tenaculum, saw, bone forceps, artery forceps, needles, tourniquet, and elastic bandage. The knife should be about twice the length of the diameter of the limb. The catling is a double-edged knife, the two edges being parallel until they converge to form the point; the scalpel is large and strong, having a firm handle. The saw (Fig. 328) should have a strong back and be well set. The bone forceps should be cutting. The tourniquet should be strong (Fig. 203), and applied as in Fig. 204. The elastic bandage is seen in Fig. 200, and its application in Fig. 201. The artery forceps may be dog-toothed (Fig. 206) or with a slide. There should be six or more catch forceps (Fig. 207).

The *time of the operation* must be fixed with due regard to the cause which necessitates the amputation and the condition of the patient. There is a time when interference must be avoided rather than courted, but the limits of the two periods are not always well defined, and must be left to the judgment of the surgeon in each individual case. In general, it may be advised, thus: (1) injuries necessitate immediate amputations, but the operation should not be performed during the period of reaction from shock; (2) if the disease is acute, avoid the period of active inflammation and rapidly-spreading gangrene; (3) in chronic affections the surgeon should regulate the time of operation according to the principles detailed.

The *place of amputation* must be determined with regard (1) to the safety of the patient, and (2) to the serviceableness of the resulting limb. Divisions of amputations based on the place of operation—namely, (1) in the continuity of the shaft; (2) in the contiguity or articulation of bones—are now comparatively unimportant, as experience proves that both for safety to the patient and serviceableness of stump no distinction should be made between amputation in the continuity and contiguity, with the exception of the ankle. In the upper

extremity all the conditions unite in favor of the least possible sacrifice of parts, for the safety of the patient is in proportion to the distance of the wound from the body; and the value of the stump in prehension depends upon the number of articulations preserved. In the lower extremity the same rule applies to the wound, but as the stump is to be used in locomotion, it requires breadth and firmness to sustain contact with the artificial appliances used in progression, and hence a place of amputation must be selected which will secure these conditions. This place is not always the farthest point from the trunk at which an amputation could be performed in a given case. But in practice it is not difficult to harmonize the two indications: when the amputation nearer the trunk would give the better stump, the danger of the wound is not

FIG. 328.

Amputating saw.

so much greater, generally, as to forbid accepting the slightly increased risk for the lifelong advantage gained.

The *immediate preparation for an amputation* should include all of the appliances necessary to render the wound entirely aseptic, as fully stated in the section giving the details of an antiseptic operation. The limb to be amputated should be scrupulously cleansed, disinfected, and shaved as directed on the day preceding the operation. When other preparations are complete, apply the elastic bandage from the extremity to a point sufficiently above the place of the division of the bone to prevent its interfering with the formation of the flaps (Fig. 329).

FIG. 329.

Elastic bandage in amputation at the knee-joint.

The *method of operation* should aim to secure a well-nourished covering of the stump, neither scanty nor redundant, and freely movable cicatricial tissue. To obtain such results, (1) the soft parts must be very nicely adapted to the surface to be covered and well supplied with blood-vessels; (2) the cut surface of bone must be immediately covered by the periosteum or the deep fascia of the part, in order to prevent the super-

ficial fascia and integument from becoming too firmly attached by the cicatricial tissue to the end of the bone. These results are secured by raising the periosteum with the soft tissues and applying it to the cut end of the bone. The objection to the periosteal covering of the bone that osteophytes are liable to form on the extremity and render the stump tender are trivial when compared with the advantages which follow the protection which it affords from necrosis and osteomyelitis, and the basis which it forms for a movable covering. If osteophytes become troublesome, they may readily be removed by a slight operation. It also frequently happens that the mutilation of parts by the injury is so great that the surgeon can form the coverings of the stump by no fixed rules, but must exercise his ingenuity in patchwork. If the conditions essential to a sound and useful stump are constantly kept in view, any of the stereotyped or extemporized methods may, with patience and dexterity, be made to yield good results. The recognized methods of amputation are: (1) the circular; (2) the single flap; (3) the double flap; (4) the rectangular flap; (5) the bilateral flap; (6) the periosteal flap.

The *circular operation* can be executed more quickly by the following than by the ordinary method: Stand upon the right side of the limb, the left foot thrown forward and placed firmly upon the floor, the right knee bending sufficiently to give freedom of motion to the body; grasp the limb above the point of operation with the left hand, and take the handle of the knife between the thumb and fore and second fingers of the right hand, lightly supported by the other fingers; stooping sufficiently to allow the right arm to encircle the limb readily, carry the knife around until the blade is nearly perpendicular to the long axis of the limb on the side next to you with the point downward and the hand above the limb. Commence the cut with the heel of the knife, giving slightly sawing motions, and bring the hand under the limb, and then directly upward upon the side next to you, until the heel touches the point of commencement; the handle of the knife held thus delicately will change its relative positions as it passes around the limb without the slightest embarrassment to the operator. The ease with which the incision is completed will depend much upon whether it commences well down upon the side of the limb next to the operator; raise the skin from the first layer of muscles by dissection, and turn it upward, two or three inches according to the diameter of the limb, like the cuff of a coat. Divide the first layer of muscles at the margin of the retracted integument by the circular incision, as of the skin; raise this layer with the knife and draw it still farther upward; divide the last layer of muscles down to the bone (Fig. 330) by the same sweep of the knife as before given. Saw the bone at the apex of the cone.

The *single flap*, or a short anterior and long posterior flap, is performed as follows: Stand upon the right side of the limb; grasp the thigh with the left hand, placing the fingers and thumb upon opposite points; then apply the heel of a long amputating knife on the farther side of the limb at the ends of the fingers, and draw it in a semicircular direction over the limb to the end of the thumb; with this single sweep divide all the soft parts down the bone: without entirely removing the knife withdraw it sufficiently to enter the point at the angle of the wound, and transfix the limb, passing under the bone, and emerging at the angle of the wound

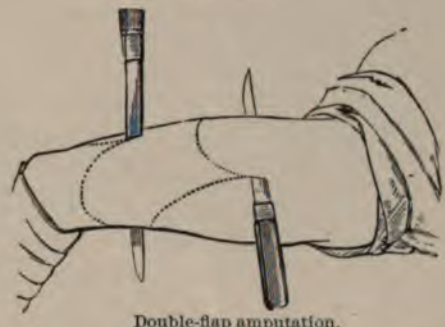
on the opposite side; make a flap of the requisite length from the posterior part of the thigh. The flaps are retracted, the knife carried around the bone, and the saw applied at the highest part of the wound.

Double flaps are formed as follows: Grasp the soft parts and bring them forward; transfix the limb, the knife grazing the upper surface of

FIG. 330.

Circular amputation.

FIG. 331.



Double-flap amputation.

the bone, and make a short anterior flap; reintroduce the knife, and, passing under the bone, make a posterior flap longer than the anterior to compensate for the greater retraction; complete the operation as in the former method. Flaps may also be made from the sides of the limb by introducing the knife in the centre of the limb directly down to the bone, on one side of which it is passed to the opposite side of the limb, and a flap is then formed (Fig. 331); the knife is reintroduced and a flap made from the opposite side; the flaps are strongly retracted and the bone sawed.

The *rectangular flap* method is as follows: Make a longitudinal incision on either side of the limb (Fig. 332), in length equal to two-

FIG. 332.

Lines of incision in Teale's amputation.

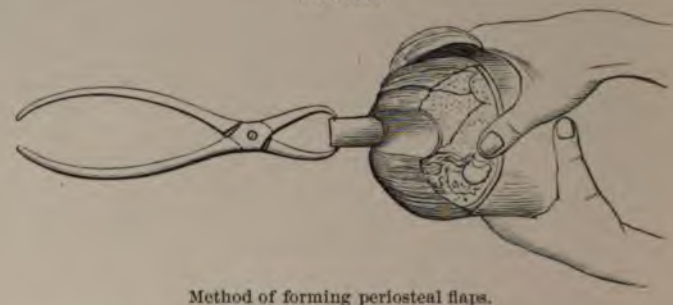
thirds of the circumference of the limb at this part; make a second incision to the bone;, unite the lower extremities of these two incisions; raise this quadrilateral flap from the bone; make a third incision transversely down to the bone, forming the posterior flap; raise both flaps and firmly retract them; saw the bone at the junction of the flaps, and unite the flaps.

Double flaps of the integuments and circular incision of the muscles require that the flaps should be sufficient to meet without effort, should correspond in size, and should not be made too arched; in dividing the muscles the knife, unless the limb be of unusual dimensions, should be carried down to the bone at once, and this can only be done by the application of considerable force, great care being taken that the muscular mass behind the bone be not pushed before the knife, but divided without displacement from its natural relations to the parts around. When the

limb is very large it would be well to divide the superficial muscles first, and allow them to retract before the division of the remainder.

The *periosteal flap* is most perfect when made as follows: Make a circular incision directly down to the bone; saw the bone; while an assistant grasps the extremity with stout forceps, the operator raises the periosteum, beginning at the extremity of the cut bone, separating its

FIG. 333.



Method of forming periosteal flaps.

attachments to the linea aspera with the knife; the periosteotome may be used, but in general the thumb-nails will be found most efficient. The periosteum, thus raised, covers the central part of the flap (Fig. 333), and when the flap is brought over the extremity the periosteum makes a perfect covering, and the tissues between the skin and periosteum, being uninjured, rapidly unite.

FIG. 334.

A stump showing mode of applying sutures and drainage-tube. A drainage-tube is shown at the left.

The *bone* must always be divided as follows: The periosteum having been raised as high up in the flap as possible, first apply the heel of the saw and draw it slowly but firmly across the bone to make a groove; then move it rapidly until the bone is nearly divided, when it is to be moved more slowly to avoid splintering the last connections; with the bone forceps clip off any sharp or projecting edges and bevel the end of the bone smoothly. Where there is a single bone it will be

found easier to apply the saw nearly perpendicularly on the side opposite to the operator; where there are two bones the saw should be first and last applied to the larger and firmer bone, the smaller bone being completely divided while the saw is engaged in the larger bone.

The *wound* must be closed and dressed according to the principles already given. The application of hot water (130° F. to 140° F.) by rapid douches to amputation wounds is an excellent method of arresting hemorrhage and preparing the surfaces for prompt union. The hot water must not be allowed to remain in contact with the limb. The vessels having been secured, if the fibrous sheaths are seen, as in amputations at the metacarpo-phalangeal articulations, close them with two or three fine sutures. Then close the wound with two or three deep and several superficial interrupted sutures (Fig. 334); place in the angles of the wound proper drainage-tubes so as to relieve it of all accumulating fluids; support the parts in such manner by splints, or slings, or pads, that it need not be moved in dressing; apply such dressings as will support and protect the wound, but admit of easy change.

I. AMPUTATIONS IN THE HAND.

Operative and mechanical surgery unite in enforcing the rule that in the hand no part should be removed that can be saved; no instrument-maker can contrive anything as useful as a finger. A great variety of methods of operation have been devised to meet the emergencies which arise from injuries of the hand requiring amputation (Fig. 335).

FIG. 335.

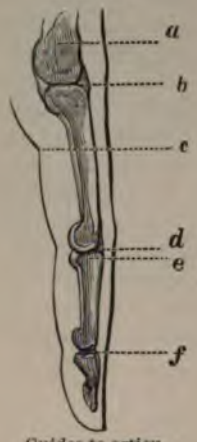
A, disarticulation of phalanx, palmar flap; *B*, amputation in continuity, circular; *C*, metacarpo-phalangeal disarticulation; *D*, amputation of a metacarpal bone in continuity; *E*, disarticulation of little finger; *F*, dislocation of fifth metacarpal; *G*, amputation of wrist, circular; *H*, amputation of wrist.

The *phalanges* are often injured in such a manner as to compel the surgeon to perform a circular, flap, or some modified operation to secure the requisite covering; but, when the parts will admit, a palmar flap is preferable, as the cicatrix is by this method removed to the dorsal surface, the stump is firm and well adapted for use, and the tactile sensation is less impaired.

The anatomical guides to the articulations are the transverse depressions (Fig. 336) in the skin on the palmar surface. Between the bony projections at the side of the finger, at the articulation of the second and third phalanges, a depression marks the position of the articulation; a prominence is readily detected on the dorsum of the second phalanx just in front of its articulation with the distal extremity of the first phalanx;

the articulation of the first phalanx with the metacarpal bone is immediately behind the bony prominences of the proximal extremity of the first phalanx. The transverse depressions in the skin on the palmar surface of each finger are three in number, and have the following relation to the corresponding articulations, commencing with the extremities of the fingers held in an extended position: The first depression is situated about a line

Fig. 336.



Guides to articulation.

Fig. 337.

Phalanx flexed.

Fig. 338.

The mode of holding the finger during disarticulation of the last phalanx.

and a half above the articulation, *f* (Fig. 336), between the third and second phalanges; the second depression is situated exactly over the articula-

Fig. 339.

Amputation of a finger: cutting the flaps by transfixion (Erichsen).

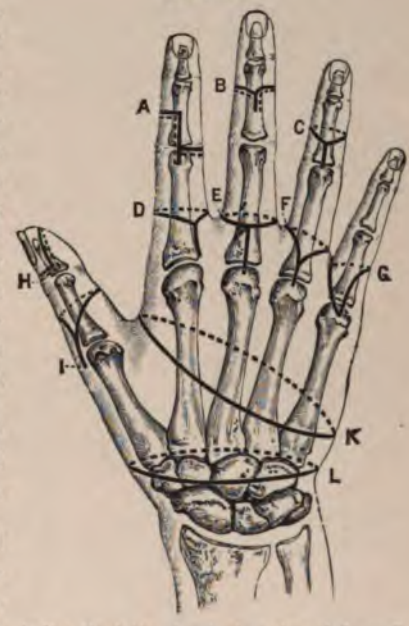
tion, *d* (Fig. 336), between the second and first phalanges; the third depression, *c* (Fig. 336), situated at the commissure of the fingers, is about an inch below the articulation, *b* (Fig. 336), of the first phalanx

with the metacarpal bone. When the finger is placed in a state of extreme flexion it will be seen (Fig. 337) that the relations of the articulation change, and hence the point at which the articulation is to be sought will depend on the position of the finger.

The *palmar flap* of a finger is made thus: Pronate the hand and require an assistant to hold apart the sound fingers; seize the phalanx with the thumb and index finger, and bend it to an angle of forty-five degrees; recognize the line of the joint as follows: On the dorsal surface there is a well-marked fold in the skin, and the joint is half a line below it; or, if this is not found, recognize the dorsal projection formed by flexion, and cut half a line beyond it; or seek the termination of the palmar fold, and find the joint half a line below it. In amputations through the shaft of a phalanx the palmar flap may be made by transfixion (Fig. 339). Make first the dorsal incision, then make a palmar flap of ample dimensions (Fig. 338, Treves).

The *oval method* at the articulations is as follows: Grasp the finger in a prone position on its palmar and dorsal surfaces by the fingers and thumb of the left hand, and flex to an angle of forty-five degrees; make an incision half an inch long on the dorsal aspect of the joint a quarter of an inch above it, *C* (Fig. 340), and carry it then across the palmar surface to the opposite side, the finger being forcibly extended; thence, the finger being again flexed, the incision is continued upward to the dorsum; dissect the borders of the wound from the head of the phalanx, enter the joint on its dorsal aspect, divide the extensor tendons and lateral ligaments, increase the flexion, with an effort to luxate the joint, which renders the flexor tendons easy of division. The oval amputation, *D* (Fig. 340, Treves), which is designed to place the cicatrix beyond pressure, is useful (Farabeuf).

FIG. 340.



A, disarticulation by single external flap; *B*, amputation by lateral flaps; *C*, disarticulation by oval or racket incision; *D*, modified racket incision for index finger; *E*, circular method, with vertical dorsal cut; *F*, incision *en croupière*; *G*, interno-palmar flap method for little finger; *H*, disarticulation by single palmar flap; *I*, disarticulation by racket incision; *K*, amputation of the fingers with their metacarpal bones; *L*, circular disarticulation at the wrist.

A *single finger* may be removed at the metacarpo-phalangeal articulation by the oval method (Fig. 340, Treves). A *single finger and its metacarpal bone* may be removed by extending the preceding incision (Fig. 340, Treves).

The *four fingers* may be removed at a single operation. The distal extremities of the metacarpal bones are not all on the same line; those of the index and ring fingers are nearly on a level, while that of the middle finger is about half a line lower, and that of the little finger is

half a line higher. The hand being well pronated, grasp the four fingers with the left hand and flex them moderately while an assistant supports the hand and retracts the skin as much as possible; with a

FIG. 341.

Amputation of all the fingers.

straight narrow knife make a curved dorsal incision, *a*, *b*, *c* (Fig. 341) with its convexity looking downward, from six to eight lines below the heads of the metacarpal bones, from the index toward the little finger if the left hand, and in the opposite direction if the right; the extensor tendons being exposed by the retraction of the integuments, which is assisted by a few strokes of the knife, open each of the metacarpo-phalangeal articulations; divide the extensor tendon first, then the lateral, and finally the palmar ligamentous attachments; carry the knife

FIG. 342. FIG. 343. FIG. 344.

Results of amputation at metacarpo-phalangeal articulation in middle, index, and ring fingers.

through the articulations to the palmar aspect of the phalanges, and cut out a flap limited anteriorly by the folds in the skin at the base of the fingers on their palmar surfaces.

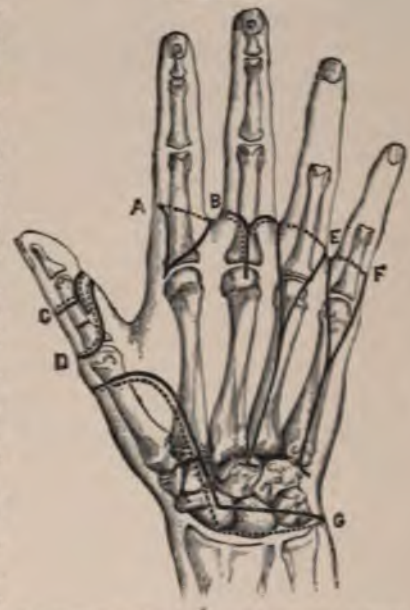
By the same method two or three fingers may be amputated, the sound fingers being held aside; the dorsal flap is then formed by the

point of the knife; or the hand may be held in the supine position and the flap made first from the palmar surface. The appearance of the stump is improved by sloping the projecting portion of each knuckle with cutting pliers.

The results of these amputations are excellent both as regards the usefulness of the hand and its appearance (Figs. 342, 343, 344).

The *thumb* may be amputated at its phalangeal or metacarpal articulation. The first is performed in the same manner as that of the fingers, but the removal at the metacarpo-phalangeal articulation requires a large flap, owing to the great size of the head of the metacarpal bone. Make an incision on the dorsal aspect, convex upward, the centre being a little above the joint, and the extremities terminating on each side at the end of the palmar transverse fold; extend the thumb and make a palmar convex incision, uniting the extremities of the first, the centre extending midway between the transverse cutaneous fold alluded to and that marking the articulation of the first and second phalanges; open the joint and complete the disarticulation, removing the sesamoid bones, *D* (Fig. 341, Treves). The palmar flap, applied to the end of the bone, should accurately fit the curved incision above. Or the flap may be made by transfixion (Fig. 346).

FIG. 345.



A, disarticulation by special externo-palmar flap; *B*, disarticulation by lateral flaps; *C*, amputation by unequal dorso-palmar flaps; *D*, disarticulation by oblique palmar flap; *E*, disarticulation of the ring finger with its metacarpal bone by racket incision; *F*, same operation upon the little finger; *G*, Dubrueil's disarticulation at the wrist.

The appearance of the hand after amputation of the thumb is good; the power of grasping is lost, but prehension remains.

A *single metacarpal bone* is removed by an incision on the dorsal aspect corresponding in length with the portion of the bone to be removed. Separate the soft parts cautiously from the bone, the knife being carried parallel with its long axis to avoid wounding the palmar arch; having made the incisions on both sides, pass the point of the knife under the bone, so as to appear at the opposite side, and then, by carrying it forward in contact with the under surface of the bone, divide the soft parts at one section: if the operation is of either the third or fourth metacarpal bone, the section should be made with the bone forceps; if of the metacarpal bone of the thumb, saw it perpendicularly to its axis; if of the index finger, make a section obliquely from without inward, the hand being supine; if of the little finger, from within outward (Fig. 347), *a*, the soft parts being withdrawn by the retractor, *b*.

Amputation through the four metacarpal bones (Fig. 348) is made as

follows: Make a palmar flap as in disarticulation of all the fingers, and a similar incision on the dorsum; pass the knife into the interosseous spaces, separate the muscular attachments, and divide the periosteum;

FIG. 346.

Amputation of the right thumb by transfixion: cutting the anterior flap.

apply a five-tailed retractor, *a* (Fig. 348), and saw the bones with a metacarpal saw, or the palmar flap may be convex forward and the dorsal flap concave, *k* (Fig. 340).

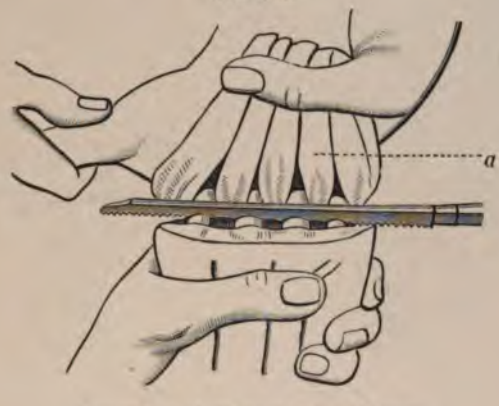
FIG. 347.

Amputation of a single metacarpal bone.

Disarticulation of the thumb with the first metacarpal bone is performed as follows: The joint is of a mixed character between arthrodial and ginglymoid; on its dorsal surface it is almost subcutaneous, but covered with thick muscle on its palmar aspect; the radial artery passes around

its ulnar side; it has a loose capsule; the joint runs in an oblique direction, in a line drawn from its external side to the root of the

FIG. 348.



Amputation of all the metacarpal bones.

little finger; its position is easily determined by the projection of the enlargement of the head of the bone on pressing the thumb into the palm; it lies an inch and a quarter below the styloid process of the radius. Hold the hand in a position between supination and pronation; make an incision along the dorsal surface of the metacarpal bone of the thumb, commencing six lines above its articulation (Fig. 349, Treves) with the trapezium, and extending through all the tissues down to the bone, to the inner side of the head of the first phalanx of the thumb, on a level with the commissure between the thumb and index finger; carrying the hand to pronation, continue the incision around the palmar surface of the phalanx to its outside, and thence to the dorsum of the metacarpal bone to join the first incision about its middle; detach the muscles and integuments from either side of the bone, and open the articulation from its dorsal aspect (Fig. 350); then, endeavoring to dislocate the bone outward, complete the division of its remaining attachments.

FIG. 349.

Disarticulation of the thumb with its metacarpal bone by a racket incision.

Disarticulation of the second metacarpal bone is rendered especially difficult on account of the prolongation of that part of its head that is in relation with the trapezoid, os magnum, and third metacarpal. The hand held in pronation, the thumb and fingers separated, make an incision, commencing about half an inch in front of the styloid process of the radius, but on a line with the second metacarpal bone, *d* (Fig. 350), and continue to the internal side of the base of the first phalanx, *a*; now carry

it around the palmar surface in the cutaneous fold—represented on the dorsum by the line *b*, *c*—to the point *c*, and thence to point of commencement, *d*; dissect the soft parts by keeping the knife close to the bone, the wound being held apart; carry the knife up along the internal side of the bone to the union of the two metacarpal bones, and, turning its edges inward, divide the inter-

FIG. 350.

Line of incision for removal of second metacarpal bone.

FIG. 351.

Amputation of first metacarpal bone.

osseous ligament, and in the same manner enter the knife into the articulation of the metacarpal bone with the trapezius; the anterior and posterior ligaments are next divided, the bone dislocated, and the knife, entered flatwise and horizontally under the upper part of the bone *a* and *b* (Fig. 351), is carried downward, completing the operation; care should be taken in dividing the ligaments not to penetrate any adjoining articular cavity.

Disarticulation of the fifth metacarpal bone may be performed by two methods: The unciform receives the fifth metacarpal bone upon a surface concave from behind forward; the line of articulation, if prolonged, would fall upon the middle of the second metacarpal bone. (1) Pronate the hand and commence an incision one line above the articulation *F* (Fig. 345, Treves), and carry it along the dorsum to the commissure, then under the finger, along the fold of the integument, to the opposite side, and thence back to the point of departure; dissect the soft parts from the bone and disarticulate. (2) The hand being held in a state of forced pronation, commence at the carpo-metacarpal joint with a slight lateral incision, and carry it down in a straight line to the inner border of the first phalanx of the little finger until it meets the depression at the base of the little finger on its palmar surface; then continue it around the base of the finger, following this depression exactly, and, lifting the little finger, continue the incision around to its inside and upward to join the first portion about opposite to the centre of the metacarpal bone; detach the integuments and muscles from the bone, and divide its articular connection with the point of the bistoury in the manner already described.

Disarticulation of a metacarpal bone is as follows (Fig. 345): Make a transverse incision, *E*, a little in front of the articulation, another upon the dorsum of the metacarpal bone; the disarticulation is then readily effected.

Disarticulation of the metacarpal bones of the four fingers is performed thus: Hold the hand in the position of forced supination and introduce, opposite the articulation of the fifth metacarpal with the unciform bone,

FIG. 352.

FIG. 353.

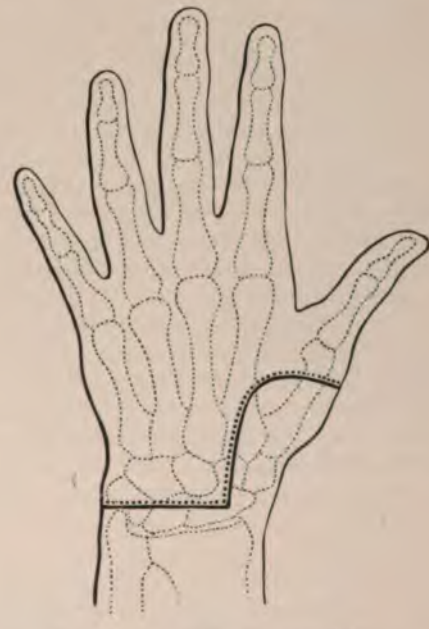
Disarticulation of metacarpal bones of four fingers.

a small, straight knife between the bones and the soft parts, carrying it a little below the projections formed by the unciform and the trapezium, so as to bring out its point below the thumb; carry the blade of the

FIG. 354.

Amputation at the wrist by long palmar flap (Erichsen).

FIG. 355.



Same disarticulation by external flap.

knife along the palmar surfaces of the metacarpal bones, and cut out a large flap of an elliptical outline, *a*, *b*, *c* (Fig. 352); turn the hand to a prone position and make a semicircular incision across its back, two-

thirds of an inch below the line of the articulations, and, carrying the knife through the tissues connecting the thumb with the index finger, *a*, *b*, *c* (Fig. 353), join the first incision; while an assistant is drawing the integuments upward hold the metacarpus in the left hand, disarticulate from the front, commencing with the metacarpal bone of the index or little finger, according as the operation is upon the right or left hand.

Disarticulation at the wrist-joint gives the best results when a flap is taken from the palmar surface of the hand. To determine the articulation, (1) strongly bend the hand backward; the summit of the angle formed by it with the forearm indicates the radio-carpal articulation; (2) feel in front of the transverse line of the radius; the joint is one line below it, and two-thirds of an inch above the crease in the skin that separates the palm of the hand from the forearm; (3) determine the summit of the styloid processes and draw a transverse line between them; this line will be two lines and a half below the joint.

A *single palmar flap* is made as follows: An assistant holds the hand in a supine position; grasp the extremity in the palm of the left hand, placing the thumb and forefinger on the extremities of the styloid processes; make a semicircular flap from the palm (Fig. 354), extending from just below the processes; dissect the flap and turn it back, make a small flap at the dorsum, and divide the tendons, the radio-carpal and lateral ligaments. An external flap (Dubrueil) may be made which will give a good covering (Fig. 355, Chalot).

AMPUTATION THROUGH THE FOREARM.

It is important to preserve as long a stump as possible of the forearm for various occupations and for the application of apparatus. It is better, therefore, to amputate near to than at the elbow-joint, for the smallest movable part of the forearm may be useful. The arteries are the radial, ulnar, and anterior and posterior interosseous; two bones of different diameters, at different parts of the limb, are to be divided.

Semicircular skin-flaps and circular of the muscles is the best method of amputation in any part of the forearm. The skin is usually too thin for one long skin-flap, and there are too many tendons for the rectangular flap. Operate thus: The arm being held with the hand supine, so as to render the bones parallel, cut from the anterior and posterior surfaces semicircular flaps of suitable length, including the tissues above the muscles; turn these flaps backward and with a long knife divide the tissues to the bone (Fig. 356); saw the two bones at the same time.

FIG. 356.

Amputation of the forearm by mixed method (Bryant).

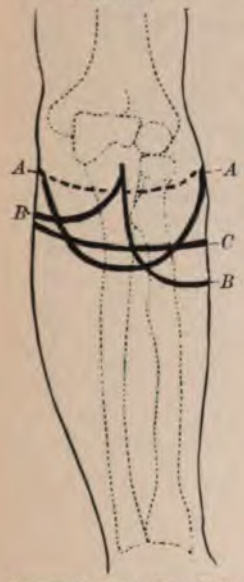
The *flap method* may be single or double. The arm being held in the position between pronation and supination, with the thumb uppermost,

so that the radius and ulna are in one line, insert a sharp-pointed knife close to the inner edge of the radius and bring it out opposite at the edge of the ulna: if a single flap is to be made, it must be taken from the anterior face, and be long enough to completely cover the stump; if a double flap is preferred, make an anterior flap the length of half the diameter of the arm and a posterior flap of equal length; turn back the flaps, divide the tendinous muscular or interosseous fibres not cut through, and divide the bones as in the circular operation.

AMPUTATION AT THE ELBOW-JOINT.

Amputation at the elbow-joint is to be preferred to amputation through the arm if no artificial arm is to be applied, as the stump is broad and firm and can be made more useful. Several methods are adapted for this articulation (Fig. 357). The circular and single anterior flap methods are generally to be preferred.

FIG. 357.



Amputation at the elbow-joint: *A*, anterior flap; *B*, external flap; *C*, circular method.

The exact position of the joint is determined by careful attention to the anatomical relations of the following osseous prominences about the joint: the epicondyles, or the most prominent points on the condyles of the os brachii are recognized, the internal more readily than the external; also the olecranon, *c* (Fig. 359); a line drawn through the lower points is, on the outside, a quarter of an inch above the interarticular line, *b* (Fig. 358), and on

FIG. 358.

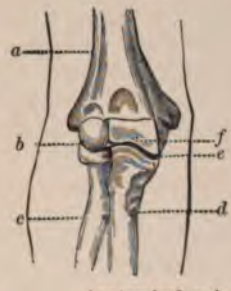


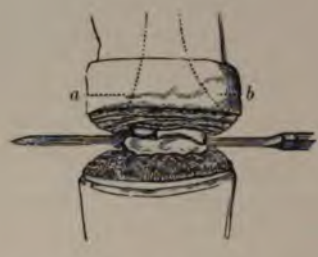
FIG. 359.

Anatomical points about the elbow-joint.

the inside three-quarters of an inch, *e*; the articulation of the radius and humerus is transverse, that of the ulna irregular, and owing to its projections must be entered externally. Two facts appear: first, that the articular interline is very oblique from without inward and from above downward; second, that it is very much below the tuberosities of the humerus. If, then, in cutting the anterior flap its base is extended up to the level of these tuberosities, it will almost always be too short to cover the bone, which will project, especially on the inside and downward; therefore enter the knife one inch below the middle projection of the epitrochlea to bring it out half an inch below the projection of the epicondyle.

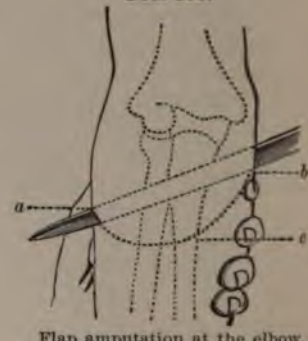
The *circular method* is as follows, *C* (Fig. 357): The arm being held in a supine position, make a circular incision through the skin only, three or four inches according to the size of the limb below the joint; dissect up the integuments to the joint and reflect backward, *a*, *b* (Fig.

FIG. 360.



Circular amputation at the elbow.

FIG. 361.



Flap amputation at the elbow.

360); divide the muscles in front and the ligaments, enter the joint, and complete the disarticulation by dividing the triceps or sawing off the olecranon; the brachial artery is divided above its bifurcation.

The *single anterior flap* is made thus: Supinate and slightly flex the limb, and make a flap from the soft parts of the joint; insert a straight knife an inch below the internal condyle, traverse the limb close to the ulna, until it appears one and three-quarters inches below the external condyle, to allow for retraction of muscles arising from the humerus; cut an inferior flap *a*, *b*, *c* (Fig. 361), about three inches in length; retract this flap, and pass the knife behind the limb, and enter the heel on the outside between the radius and os brachii, and extend the incision; draw it across the back part of the joint, dividing all the tissues to the internal angle of the wound; divide the anterior ligament and the lateral ligaments, luxate the bones forward, cut the triceps, and complete the operation.

An *external flap*, *B* (Fig. 357), may be preferred in some cases of accident: Make the flap by transfixing the limb upon the outside; insert the point of the knife just within the head of the radius; traverse the neck, cutting out a larger external flap; a second flap is made from the inside of the arm by cutting from without inward and from below upward, the soft tissues immediately covering the joint are then divided and disarticulation completed.

AMPUTATION OF THE ARM.

Amputation of the arm may be performed at any point, but, as a rule, as little should be sacrificed as possible. Owing to its uniform size and single central bone any of the different methods may be applied, but the periosteum should be raised for a covering to the bone. There are two elliptical methods: one on the posterior and the other on the anterior face of the limb, the highest point in the former being the olecranon, and of the latter the bend of the elbow. The former is to be

preferred (Fig. 362), as it furnishes an ample covering and posterior cicatrix.

The *circular operation* gives a good stump, and is as follows: Place the arm at right angles to the body; standing on the right side of the limb, make a circular incision through the integuments; roll the flap one and a half to two inches, according to the size of the limb; make a second incision at the margin of the retracted skin; divide and retract the superficial muscles, and make a third incision down to the bone; raise the periosteum an inch and saw the bone; the brachial artery lies on the inside, between the biceps and internal portion of the triceps muscles.

The *flap operation* may be single, and may be made at any point presenting on one surface a sufficient amount of tissues; two flaps of equal size are preferable generally; they are anterior and posterior; the arm being carried at a right angle with the body, grasp with the left hand the tissues on the anterior or lateral part of the arm, and, passing the knife down to the bone, carry it over to the opposite side, and cut out a flap in length three-fourths the diameter of the limb (Fig. 363); insert the knife close to the

FIG. 362.

Disarticulation at the elbow-joint by the posterior ellipse method.

FIG. 363.

Amputation of arm by flap operation (T. Bryant).

bone on the opposite side and make a similar flap; firmly retract the flaps, divide the tissues covering the bone, and saw the bone at the highest point between the flaps.

AMPUTATION AT THE SHOULDER-JOINT.

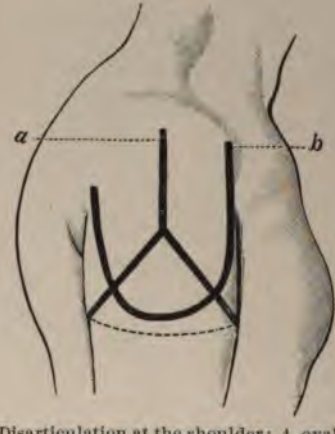
The *shoulder-joint* is arthrodial; the articular head of the os brachii is very broad, and articulates by scarcely one-third with the shallow glenoid cavity of the scapula; it is connected, too, by a loose capsular ligament; the joint is strengthened by the long head of the biceps and the muscles arising from the scapula and inserted in the vicinity of the joint; the joint is protected above by the extremity of the clavicle and the acromion process.

It is of the utmost importance to prevent hemorrhage during the operation, and to effect this object there are now entirely reliable means.

Pressure upon the subclavian with a key and seizing the flap containing the axillary artery are unsafe measures, and should be resorted to only in the absence of the proper appliances. The elastic bandage may be applied (Fig. 366) so as to render bleeding impossible either from the axillary artery or smaller vessels. Pins may be employed, as follows: Select two pins, sharp-pointed and cylindrical, eleven inches long and one-fourth of an inch in diameter near the head; introduce the first pin through the middle of the anterior axillary fold, a little nearer to the body than the transverse centre of the transverse fold made by the pectoralis major; the place of emergence should be an inch within the tip of the acromion; the point of the pin when in position should be protected by a sterilized cork. The second pin should be introduced at a corresponding point through the posterior axillary fold, the tendon of the latissimus dorsi, emerging an inch within the tip of the acromion. A piece of black-rubber tubing, half an inch in diameter, should now be wound tightly around the limb above the pins, so as to completely interrupt all circulation. The vessels should be ligated as quickly as possible, and the tubing and pins removed. Ligation of the vessels in the space between the deltoid and the great pectoral has been performed, with good results, before amputation.

The *oval method* is well adapted to cases of fracture near the joint. Make a vertical incision from the end of the acromion process over the head of the humerus down to the bone, *A* (Fig. 364); then two oblique

FIG. 364.



Disarticulation at the shoulder: *A*, oval method; *B*, method by deltoid flap.

FIG. 365.

Disarticulation at the shoulder: Spence's method.

incisions starting from the lower end of the vertical, one on the anterior, the other on the posterior, aspect of the joint, carrying them through the tissues composing the anterior and posterior walls of the axilla to the lower border of each, and dividing their attachments to the humerus. Push the edges of the wound on either side to expose the joint, and open it, making traction on the bone to put its ligament on the stretch; luxate the head of the bone, pass the knife behind it, and finish the operation by cutting directly through the tissues in the axilla which intervene between

the extremities of the incisions already made, recollecting that they contain the artery, which requires to be compressed by an assistant. The

FIG. 366.

Esmarch's tourniquet applied to shoulder.

wound which results from this operation is almost perfectly oval in shape. Or, the head of the bone may be dissected from its cavity,

FIG. 367.

Amputation at shoulder, modified oval (Spence).

with the knife held vertically, first upon one side and then upon the other, and the operation completed by dividing the axillary portion.

The *modified oval operation* (Fig. 367) is adapted to gunshot wounds. It is as follows: Slightly abduct the arm and rotate the humerus outward; commence an incision just external to the coracoid process, and carry it down through the clavicular fibres of the deltoid and pectoralis major muscles to the humeral attachments of the latter muscle, which must be divided; then carry the incision across and through the lower fibres of the deltoid toward, but not through, the posterior border of the axilla; next carry an incision through the skin and fat only from the point where the straight incision terminated, across the inside of the arm, to meet the incision at the outer part. If the fibres of the deltoid have been thoroughly divided, the flap, together with the posterior circumflex artery, can be easily separated by the point of the finger from the bone and joint, and drawn upward and backward, so as to expose the head and tuberosities. Now divide the tendinous insertions of the capsular muscles, the long head of the biceps, and the capsule, and disarticulate and divide the remaining attachment (Fig. 367).

The *single-flap method* may be followed when there is no fracture, *B* (Fig. 364): the arm being held away from the trunk, grasp the deltoid in its entire length and thickness in the left hand, and with the right pass a double-edged knife through its base, under the acromion, and, grazing the surface of the humerus, cut an external and superior flap of sufficient extent; an assistant raises it; then, by approaching the arm to the body, expose the tendons of the muscles inserted into the head of the humerus and cut them; grasping the arm with the left hand, dislocate the head of the bone outward; pass the knife behind it and incise the soft parts, while an assistant seizes the flap in such a manner as to prevent hemorrhage from the divided axillary artery, and, if the tissues are hardened, taking care not to allow air to enter the veins.

The *double-flap* is as follows: The arm is kept close to the trunk, the head of the humerus being pushed upward and outward as much as possible; recognize the exact position of the acromion and coracoid processes; on the left shoulder enter the point of a long knife almost parallel with the humerus at the outer side of the posterior border of the axilla, in front of the tendons of the latissimus dorsi and teres major muscles, *c* (Fig. 368). As the knife passes in the plane of its blade it should form an angle of thirty-five degrees with the axis of the shoulder, and its point should graze the posterior and external surface of the humerus until it reaches the under surface of the acromion; at this point the handle of the knife should be raised and its point lowered, so that it is brought out below and in front of the the clavicle, *a*, in the triangular space between the acromion and coracoid processes, which is bounded posteriorly by the clavicle. Make the knife cut its way outward around the head of the humerus, *b*, and as soon as

FIG. 368.

Double-flap amputation at shoulder.

it becomes disengaged from beneath the acromion process carry the arm away from the trunk; now grasp the deltoid muscle with the left hand, raising it as much as possible from the bone, and carry the knife directly downward, grazing the bone, and cut out a semicircular flap about three inches in length. In making this flap the upper part of the capsule of the joint should be divided as well as the tendons of the latissimus dorsi, teres major and minor, and part of the deltoid; raise the head of the humerus from the glenoid cavity, pass the blade of the knife behind it, and carry it downward and forward, grazing the humerus, to cut out the internal flap, and at this moment the axillary artery should be compressed by an assistant.

Amputation of the arm and scapula may be performed for severe injuries and malignant growths. Treves-Berger's operation is as follows: Place the patient on the back, the shoulders raised, and make an incision along the clavicle down to the bone, commencing at the external border of the sterno-mastoid and ending just beyond the acromio-clavicular articulation (Fig. 369). The periosteum being separated at the

FIG. 369.

Interscapulo-thoracic amputation.

inner extremity of the wound, pass a blunt hook carefully around the bone at this point and divide it, either with the chain or the keyhole saw; now separate the periosteum from the outer portion of the clavicle, and saw the bone again at the junction of the middle and outer thirds; remove this middle portion of the clavicle.

The subclavius muscle is next turned outward so as to expose the vessels, and double ligatures are applied, first to the artery, and then to the vein, and the vessels are divided between these ligatures. The patient is now placed on the edge of the table on a hard cushion; the scapular region is free; an assistant draws the limb away from the body, and the surgeon takes a position on the inner side of the limb. Commence an incision at the centre of the clavicular incision; curve it downward and outward, passing just outside of the coracoid process, along the deltoid muscle, parallel to, but to the outer side of, the groove between that muscle and the pectoralis major; the incision should now

cross the lower margin of the pectoralis major and pass transversely across upon the axillary surface of the arm to the lower margin of the tendons of the latissimus dorsi and teres major, and, while the arm is raised, be continued downward and inward to the posterior surface of the inferior angle of the scapula, along the groove between the vertebral border of the scapula and the mass of muscle composed of the teres major and the latissimus dorsi; dissect up this flap, dividing the pectoralis major where it is becoming tendinous, and the minor at its insertion into the coracoid process; divide the brachial plexus close to the first rib, also all other connections, thus freely opening the axilla. The arm is now carried across the chest and the scapular region well exposed; the operator takes his position on the outside of the extremity, and makes an incision from the outer end of the clavicular incision backward directly over the spine of the scapula to the termination of the anterior flap at the inferior angle of the scapula; the attachments of the trapezius to the clavicle and scapula are divided, then the omo-hyoid, levator anguli scapulæ, rhomboideus minor and major, and the serratus magnus; sever the remaining connections while an assistant moves the limb so as to expose attachments.

Amputations of the arm, scapula, and clavicle have been performed for malignant diseases by extension of this method.

FIG. 370.

Surgical guide to anatomy of foot: *A*, cuboid bone; *B*, articulation of scaphoid and internal cuneiform; *C*, articulation of internal cuneiform and first metatarsal; *D*, articulation of astragalus and scaphoid; *E*, os calcis; *F*, articulation of os calcis and cuboid; *H*, articulation of cuboid and fifth metatarsal.

AMPUTATION OF THE FOOT.

In all amputations of the lower extremity the surgeon should be governed in the selection of the point of operation and the method to be adopted (1) by the mortality of the operation in question; (2) by the adaptability of the stump to the most serviceable artificial limb for locomotion.

Amputation of the phalanges in the continuity or contiguity is performed by the same rules as have been given for similar amputations of the fingers, a flap being generally formed from the plantar surface.

Disarticulation of single toes must be undertaken with due regard to the following facts: The extremity of the first metatarsal bone is large, and requires a very liberal flap to cover it; on the plantar surface of the articulation are two or three sesamoid bones; the interarticular line is farther from the interdigital fold than in the hand, but the second space is much nearer the joint than the others.

The *oval method* is as follows: Holding the toe with the finger and thumb, commence an incision over the joint, *A*, *B* (Fig. 371), and carry it downward and forward along the side of the toe to the commissure of the toes, around under the toe, along the transverse linear depression to the opposite side, and thence up to the point

of commencement; divide the extensor tendons and lateral ligaments with the point of the knife, open the joint, and complete the disarticulation by cutting the tissues upon the under part of the joint.

The *single plantar flap* requires a transverse incision over the joint, and lateral incisions to divide its connections; depress the toe and pass the knife through the joint and along the under surface of the bone until a sufficient flap is formed; or, dissect off the flap from before backward. The *lateral flap* for the great and for the little toe is made on the same plan as the oval (Fig. 371).

Disarticulation of all of the toes through the metatarso-phalangeal articulations requires the operator to note that these joints, *a*, *b*, *c*

FIG. 371.

A, disarticulation of the second phalanx of a toe by the racket or oval incision; *B*, disarticulation of the great toe by the racket or oval incision.

FIG. 372.

Disarticulation of the great toe by internal plantar flap.

(Fig. 373), represent a curved line with its convexity downward, due to the difference in the metatarsal bones; the second is half a line longer than the first, the third is half a line shorter than the second, the fourth is half a line behind the third, the fifth is still farther behind. The single flap is made in nearly the same manner as in amputation of all the fingers. If the operation is on the left foot, grasp the toes with the left hand, the thumb applied to the backs of the toes, and make a semicircular incision in front of the joints, commencing at the internal side of the head of the first metatarsal bone, and ending at the external side of the fifth; dissect up the flap, open the joints, and divide the lateral ligaments with the point of the knife; now pass the knife behind the phalanges and cut a flap from the plantar surface. Or, make the plantar flap by extending an incision along the cutaneous fold at the base of the phalanges and dissecting backward (Fig. 374).

FIG. 373.

Amputation of the toes.

Amputation through the metatarsal bones is performed with plantar and dorsal flaps, as on the metacarpus. Make a curved incision on the dorsum of the foot, convex downward, dividing the soft parts down to the bone; transfix the plantar surface, grazing the bones, and make a

flap reaching to the commissure of the toes; divide the interosseous muscles with the point of the knife, apply a six-tailed retractor, and divide the bones with a fine saw (Fig. 375).

Disarticulation of the first metatarsal bone is best performed by the oval method. The articulation is one or two lines behind the first projection found on the posterior portion of the metatarsal bone, and an inch anterior to the prominence of the scaphoid, *E* (Fig. 370); the direction of the line of articulation is from within forward and outward.

FIG. 374.

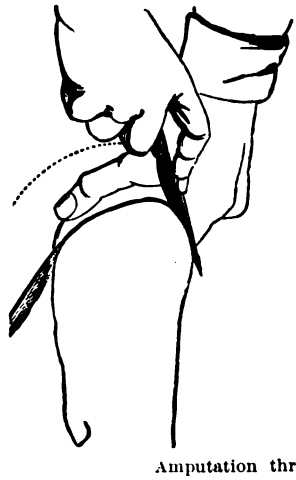
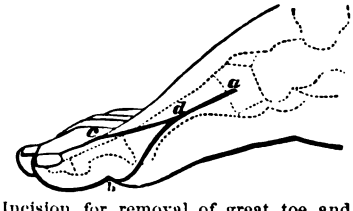


FIG. 375.

Amputation through the metacarpal bones.

Commence two lines behind the joint, *a* (Fig. 376), an incision directed obliquely from within outward to the commissure of the toes, *c*, and pass around the base of the first phalanx, following the crease on its plantar surface; withdraw the bistoury and replace it on the internal side of the phalanx, *b*, in the inferior angle of the incision, ascend on the internal side of the metatarsal bone and phalanx, and, following a line slightly oblique from within outward, rejoin the point of commencement; the skin being cut, divide successively in the whole extent of the incision the extensor tendons of the toe and fibres of the dorsal interosseous muscle. Dissect out the bone (Fig. 377), leaving the sesamoid bones in the phalangeal articulation; divide the internal ligament, holding the point of the instrument perpendicularly and the edge slightly oblique from within outward and from behind forward to follow the direction of the joint; next divide the superior ligament, and direct the bistoury upward and push its point at an angle of forty-five degrees into the interosseous space formed by the external surface of the first cuneiform and the extremity of the second metatarsal bone; when the point

FIG. 376.

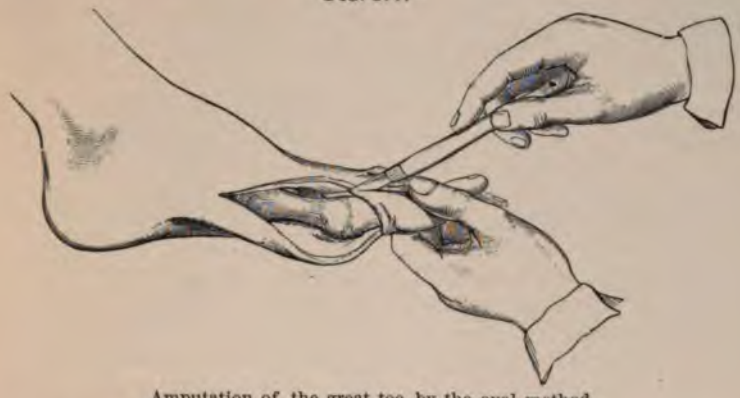


Incision for removal of great toe and metatarsal bone.

has penetrated to the plantar layer raise the blade again to the perpendicular and divide the interosseous ligament.

Disarticulation of the fifth metatarsal bone is by the oval method. This bone articulates with the cuboid, *f* (Fig. 370), by a triangular sur-

FIG. 377.



Amputation of the great toe by the oval method.

face, and with the fourth metacarpal; it has a tubercle on the external part of its base, which is easily felt and into which is inserted the peroneus brevis muscle; the line of the articulation is obliquely forward and inward. Commence an incision just behind the joint, carry it forward toward the commissure, thence under the toe, along the transverse linear depression to the opposite side, and then along the external margin to the point of departure; dissect (Fig. 378) the soft parts from the bone and enter the joint found just behind the tubercle; from the outside divide the ligaments which unite it to the fourth metatarsal, and complete the operation by dividing the plantar ligaments.

FIG. 378.

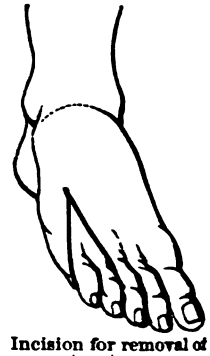
Amputation of the little toe and its metatarsal bone by the racket-shaped incision.

Disarticulation of single metatarsal bones may be made by the oval method, as described for similar operations on the hands.

Disarticulation of the two outer metatarsal bones is made as follows:

Commence an incision a finger's breadth behind the joint of the fifth metatarsal bone, in the middle, between the articulation of the two bones; carry it forward to the commissure, then along the under surface in the transverse line to the outer side of the little toe, and thence back to the beginning; dissect the soft parts from the bones, divide the lateral ligament, and disarticulate the joints by entering them from the outside and following the line above given (Fig. 379).

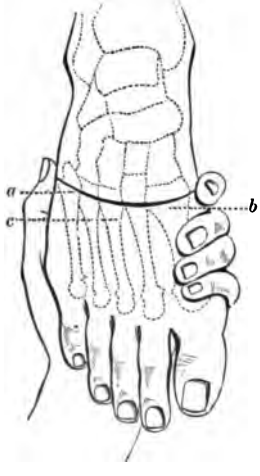
FIG. 379.



Incision for removal of two toes.

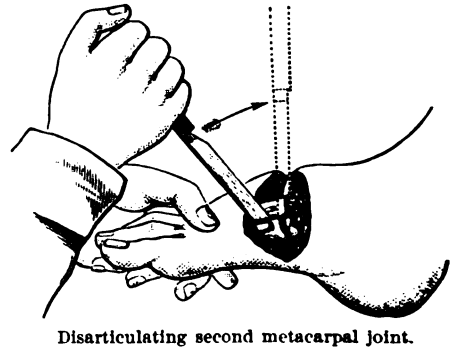
Disarticulation at the tarso-metatarsal articulation (Hey's operation) is effected as follows: Grasp the sole of the foot (the right) with the left hand, placing the thumb on the outer side of the proximal end of of the fifth metatarsal bone, *a* (Fig. 380), and the index finger at the extremity of the first metatarsal bone, or one inch anterior to the prominence of the scaphoid, *b*; make a semilunar incision, with its convexity looking downward, from without inward, across the dorsum of the foot, passing about half an inch below the articulation down to the bones; divide the dorsal ligaments with the point of the knife, carrying it along the line of the articulation from without inward, recollecting that the articulation of the second metatarsal lies four lines behind the first and third: this mortise, containing the head of the second metatarsal, is opened by entering the knife between the internal cuneiform and the head of the first, its edge being turned upward and making an angle of forty-five degrees with the axis of the foot (Fig. 381); now carry the

FIG. 380.



Points of incision for removal of foot at tarso-metatarsal articulation.

FIG. 381.



Disarticulating second metacarpal joint.

knife up to a right angle, its point traversing the whole of the inner surface of the mortise, in order to ensure the division of the interosseous ligament; then divide that on the outer surface, depress the metatarsus to separate the articular surfaces, and divide the remaining ligamentous attachments, especially on the plantar aspect of the articulation, so that the knife may be readily carried beneath the heads of the metatarsal bones; cut out from the sole of the foot a flap

somewhat larger at its internal than at its external part (Fig. 382), and extending internally nearly to the base of the great toe; externally it may be of less extent. Do not include the sesamoid bones in the flap.

FIG. 382.

Plantar flap.

FIG. 383.

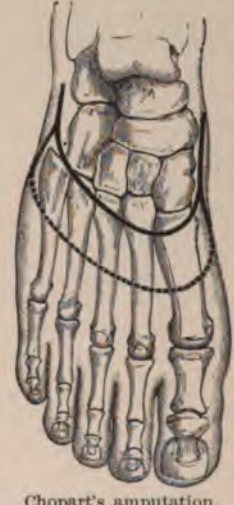
Formation of plantar flap.

Or, a plantar flap may be made by carrying a curved incision from the internal extremity of the dorsal incision (Fig. 383) to the sesamoid bones, then curving forward across the sole of the foot to the junction of the anterior with the middle third of the fifth metatarsal bone, thence to the beginning of the dorsal incision.

FIG. 384.

Stump after amputation.

FIG. 385.



Chopart's amputation.

The stump after this operation is useful (Fig. 384).

Medio-tarsal disarticulation (Chopart's) is still approved and performed by surgeons, but is much inferior in utility to Syme's amputation (Figs. 386, 387, Treves).

The line of articulation, *D* (Fig. 370), is determined as follows: On the internal surface of the foot, about one inch below the end of the malleolus, two prominences are readily recognized on the same plane: the joint is midway between them; on the external side it is six lines behind the prominence of the fifth metatarsal bone. The centre of the articulation is immediately in front of the head of the astragalus, which is made prominent by extending and abducting the foot. The line of the articulation is changed according as the foot is flexed or extended;

when it is flexed the articular surfaces of the astragalus and calcaneum are nearly on the same line; when extended the calcaneum is at least three lines in front. Holding the foot (left) in the hand, the palm on

FIG. 386.

Outer side of foot: *A*, Chopart's amputation; *B*, Syme's amputation; *C*, subastragaloid amputation; *D*, line of section of bone in Syme's amputation.

the dorsum, with the thumb on the outside and the index on the inside, define the two extremities of the articulation; make a semilunar incision between these two points, the middle of which is half an inch beyond the articulation; then, passing the heel of the knife under the left thumb, its handle inclined as above, open the joint in the direction pointed out; when the joint is half opened, carry the knife in front of the head of

FIG. 387.

Inner side of foot: *A*, Chopart's amputation; *B*, Syme's amputation; *C*, subastragaloid amputation.

the astragalus, and cut the dorsal ligaments without penetrating between the bones; carrying the knife to the other side of the foot, the heel inclined toward the toes at an angle of forty-five degrees, finish opening the external side of the joint; the dorsal ligaments being thus divided, push the point of the knife under the external and anterior side of the astragalus, with its edge directed forward, and cut the interosseous ligament in the direction of the articular surface of the calcaneum; the joint

being now open, carry the knife under the plantar ligaments and pass it under the bones, grazing them, to cut a sufficient flap (Fig. 388), avoid-

FIG. 388.

Chopart's amputation.

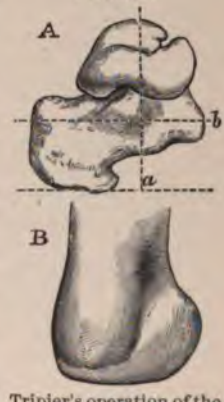
FIG. 389.

Stump after Chopart's amputation.

ing the protuberances of the cuboid and scaphoid, and, farther on, of the first and fifth metacarpal bones; the foot during this time is held in the horizontal position; raise the handle of the knife slightly, to follow more exactly the concavity of the tarsus and metatarsus.

Disarticulation of the tarsus under the astragalus (subastragaloid) may be practised as follows: Commence at the outer edge of the insertion of the tendo Achillis, *A* (Fig. 391), and make an incision through the skin forward two fingers' breadth below the malleolus, to within a finger's breadth of the upper part of the base of the fifth metatarsal bone; now carry the incision upward, forward, and inward, so as to reach the inner margin of the tendon of the extensor proprius pollicis just at the first metatarsal articulation, *C* (Fig. 387); then cut downward and forward, and enter the sole a finger's breadth in front of the dorsal wound; next carry the incision with a gentle forward curve, outward and backward, until it can be made continuous with the first portion of the wound below the outer malleolus, *D* (Fig. 386). Retract the integument half an inch, and divide the dorsal and plantar structures and tendo Achillis; separate them from the bones, great care being taken to preserve uninjured the vessels contained in the inner part of the plantar flap; now disarticulate the cuboid and scaphoid from the astragalus, passing the knife between the astragalus and os calcis, so as to divide the interosseous ligament; separate the soft parts from the under surface of the os calcis while so twisting the foot as to make the tissues tense; disarticulate the os calcis from the astragalus.

FIG. 390.



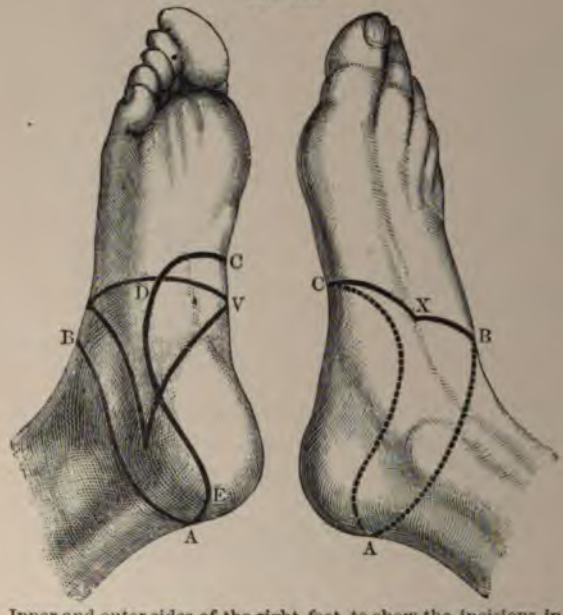
Tripier's operation of the foot.

In Tripier's operation the os calcis is sawn through in a direction

from behind and within forward and outward, so as to leave a surface which will be at right angles with the axis of the tibia when the limb assumes the position for walking, *A*, *B* (Fig. 390).

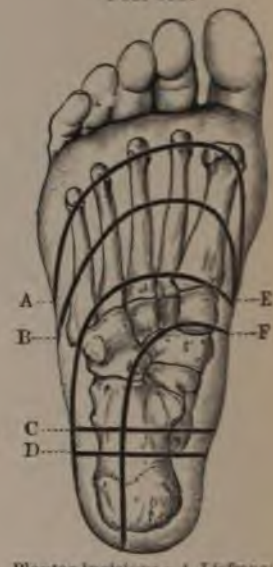
Farabeuf makes a large internal and plantar flap, *A* (Fig. 392, Treves). Begin at the outer margin of the tendo Achillis, curve the

FIG. 391.



Inner and outer sides of the right foot, to show the incisions in Farabeuf's subastragaloid amputation: *V*, the lines of Verneuil's subastragaloid amputation. (For other references see text.)

FIG. 392.



Plantar incisions: *A*, Lisfranc; *B*, Chopart; *C*, Pirogoff; *D*, Syme; *E*, Farabeuf's subastragaloid amputation; *F*, Farabeuf's amputation at the ankle.

incision up to a point an inch below the external malleolus, then forward to *B* on the line of the fifth metatarsal bone, with the joints between the scaphoid and cuneiform bones; then across the dorsum to *X* (Fig. 391), to the tendon of the extensor proprius pollicis; the incision crosses the inner border of the foot along the line of the cuneo-metatarsal joint; then across the centre of the sole to *D*, whence it curves back along the outer border of the foot to the external border of the os calcis, *E*, then upward to the point of commencement, *A*.

Verneuil commences the incision at about the same point, and carries it forward to within an inch of the posterior and internal extremity of the fifth metatarsal bone, thence with a downward curve across the dorsum of the foot to the middle of the internal cuneiform bone, thence across the sole of the foot from within outward and from before backward to the commencement (Fig. 391, Treves).

AMPUTATION AT THE ANKLE-JOINT.

Disarticulation of the ankle-joint with a heel-flap has justly been regarded as one of the greatest improvements in amputation of modern times. Not only is the mortality of this operation very small, but when

compared with the stumps made at any other point of the foot or leg, those made at the ankle-joint have proven eminently superior, being less subject to such untoward complications and sequelæ as ulcers, congestions, necrosis, and chronic tenderness, which impair the subsequent usefulness of appropriate and well-adapted compensative apparatus. The broad articular surface of the lower extremity of the tibia, with its internal projection, the internal malleolus, and the large projecting extremity of the fibula, the external malleolus, form a mortise to which the lateral and upper surfaces of the astragalus are so accurately adapted that there can be no lateral motion, and disarticulation can only be accomplished when the foot is firmly extended and the knife penetrates the anterior part of the articulation.

Syme's amputation is as follows: Place the foot at a right angle to the leg; enter the knife at the point of the external malleolus, *B* (Fig. 386), and carry it directly across the sole of the foot to a point opposite, or six lines below the internal malleolus, *B* (Fig. 387); the posterior tibial artery divides beneath the internal annular ligament into the internal and external plantar arteries, and if the incision extends to the point of the internal malleolus, the vessel may be divided; join the two extremities of this incision by an anterior incision in a direct line over the instep, so that the cicatrix may come well in front (Fig. 393). In dissecting the posterior flap, place the fingers of the left hand upon the heel, and with the thumb press the edge of the flap firmly backward, cutting between the nail of the thumb and the tuberosity of the os calcis

FIG. 393.

Syme's amputation of the foot: anterior incision and disarticulation.

FIG. 394.

Syme's amputation of the foot: cleaning the os calcis.

(Fig. 394), so as to avoid lacerating the soft parts; the tendo Achillis is exposed and divided. Disarticulate the foot and saw off the malleoli, *D*

(Fig. 386); leave the articular extremity of the tibia uninjured, for it is better not to interfere with the bone if it is healthy.

There are many methods of modifying the construction of flaps to cover the ends of the tibia and fibula, adapted to the various forms of injury of the soft parts: all coverings, whether from the sole, the lateral surfaces, or from the dorsum of the foot, are useful, and should be preserved for that purpose when the heel-flap is wanting. In the first example insert the knife in the middle line of the posterior aspect of the ankle, on a level with the articulation; carry it downward obliquely across the tendo Achillis toward the external border of the plantar aspect of the heel, along which it is continued in a semilunar direction; curve the incision across the sole of the foot, and terminate it on the inner side of the tendon of the tibialis anticus about an inch in front of the inner malleolus; carry the second incision across the outer aspect of the ankle in a semilunar direction, between the extremities of the first incisions, the convexity of the incision downward, and passing half an inch below the external malleolus. In Roux's operation make an incision from the junction of the tendo Achillis with the os calcis around the external surface of the foot immediately below the external malleolus; then carry it inward toward the internal border; curve forward and about an inch in front of the ankle-joint; then pass along the internal border of the foot to the point of departure.

In *osteoplastic amputation at the ankle-joint* (Pirogoff) the covering of the stump consists of the posterior part of the os calcis enclosed in the integument of the heel. The results are favorable, but the additional length of limb is not desirable for an artificial limb. Commence the incision close in front of the outer malleolus; carry it downward and forward nearly to the posterior extremity of the fifth metacarpal bone, into the sole of the foot, *A* (Fig. 395), then transversely across the sole, and

FIG. 395.

Pirogoff's amputation: *A*, cutaneous incision, outer side; *B*, line of section of the bones.

lastly obliquely upward and backward to the inner malleolus; terminate it a couple of lines anterior to the malleolus; divide all the soft parts at once quite down to the os calcis; now connect the outer and inner extremities of this first incision by a second semilunar incision, the convex-

ity of which looks forward, carried a few lines anterior to the tibio-tarsal articulation; cut through all the soft parts at once down to the bones, and then proceed to open the joint from the front, cutting through the lateral ligaments, and thus exarticulate the head of the astragalus; now place a small, narrow amputation saw obliquely upon the os calcis behind the astragalus, and saw through the bone carefully, or the anterior surface of the tendo Achillis, which is only covered by a layer of fat and a thin fibrous sheath, may be injured; raise the short anterior flap from the two malleoli, and make a section of the tibia and fibula just above the articular surfaces; turn this flap forward, and bring the cut surface of the os calcis in apposition with the cut surface of the tibia (Fig. 396); the tendons must not be cut off too near the point where their synovial sheaths are cut through; if cut too short, they conceal themselves in the fibrous canal, or, when the limb is moved, slip upward out of their sheaths. Other methods are outlined in the illustration.

FIG. 396.

Pirogoff's amputation: appearance of the parts after removal of malleoli (J. E. Erichsen).

Supra-malleolar amputation should always be preferred to any operation at a higher point, and the flap should be taken from the firmest tissues accessible. The following method (Guyon), *B* (Fig. 401), gives a good stump: Make an incision from the base of the external malleolus, posteriorly, around the external surface of the foot immediately below the malleolus, and inward toward the internal border, but curved forward to a point an inch in front of the ankle-joint (Fig. 397); make a similar incision on the internal surface, and unite the two behind by a transverse incision having a slight convexity downward; separate the soft parts from the bones, and saw the tibia and fibula at the base of the malleoli about an inch above the articular surface.

FIG. 397.

Supra-malleolar amputation.

AMPUTATION OF THE LEG.

Amputation of the leg involves new and most important principles, both in operative and mechanical surgery. At no other point is it more necessary to secure a sound and useful stump than in this part. This is due to the incessant use to which it must be applied and its exposure to injury. But it presents intrinsic difficulties in the application of the ordinary methods of amputation. This is apparent in the development of the muscles of the calf, the tapering form of the lower portion, and the subcutaneous position of the tibia. The circular flap cannot be retracted without dividing it longitudinally; the single posterior flap is of immense size, and is counteracted only by the integument of the anterior part of the leg; the double flap gives a great inequality of flaps; the

single external flap leaves the crest of the tibia but slightly covered. The results of amputation of the leg have, in consequence of these conditions, been more unsatisfactory than at any other point. Necrosis of the tibia, conical stumps, ulcerated coverings, and tender cicatrices have been the rule when the old methods have been preferred. But bilateral flaps of the soft parts and periosteal coverings of the tibia give a firm, compact, and enduring stump.

The place of division of the bone may be at any point, but at the lower part of the leg the commencement of the calf is most favorable for a symmetrical stump, and at the upper part is to be preferred a point two inches below the tubercle of the patella, which permits the knee to be bent and brings the support upon the condyles of the femur. An amputation at the latter point is indicated whenever the leg is permanently flexed either at a right or at an acute angle with the thigh. If the amputation must be very close to the joint, disarticulation should be preferred, for the risk to the patient of the knee-joint amputation is no greater than of an amputation of the extreme upper third of the leg, while its practical benefits are much superior, as confirmed by experience. The elastic bandage should be first applied to a point above the knee (Fig. 329). The bilateral flaps here recommended should be made as follows: Commence an incision with a large scalpel in the centre of the anterior surface (Fig. 398), and

FIG. 398.

Bilateral flaps.

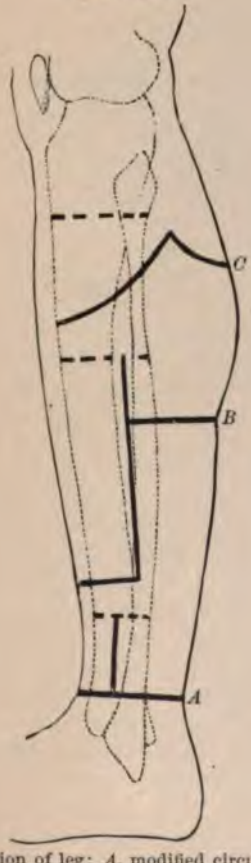
carry it downward along the side of the leg so as to make a slightly curved flap with its convexity below; after the incision has passed over the prominent part of the leg toward the posterior surface, incline it slightly upward until the middle of the limb is reached, where it should be continued directly up to the point at which the bone is to be divided; make a similar incision on the opposite side; these lateral flaps should consist of the skin and superficial fascia; dissect them upward to the extent of one inch in the leg and two inches in the thigh; now make a circular division of the muscles to the bone with a long knife; saw the bone or bones at this point, and direct an assistant to seize and hold the extremity firm with strong forceps (Fig. 333): with the periosteal knife or the thumb-nails (which are equally efficient) raise the periosteum from the tibia to the point where the latter is to be cut; divide the bone at the base of the periosteal flap. The periosteum must be cut at its attachments to the linea aspera of the bone, and should be raised only from the tibia, the fibula being first exsected. The covering thus prepared has the integument externally, the periosteum internally, while the intervening tissues, muscles, vessels, nerves have not been disturbed in the dissection; the periosteal flap falls like a hood over the end of the bone, the skin-

FIG. 399.

Stump after bilateral flaps.

flaps lie in contact without tension, and the drainage is direct from the angle of the wound beneath. When cicatrization is complete the cicatrix lies posterior to the end of the stump, the cushion is freely movable, and the bone does not undergo the usual amount of atrophy (Fig. 399).

FIG. 400.



Amputation of leg: *A*, modified circular; *B*, rectangular flaps; *C*, antero-posterior flaps, upper third.

FIG. 401.

Amputation of leg: *A*, long anterior flap; *B*, supra-malleolar amputation by long posterior flap; *C*, at the upper third.

The various other methods of operating are indicated by the illustrations (Figs. 400, 401). The rectangular flap, *B* (Fig. 400), is sometimes made in the lower part of the leg; the rules given as to the formation of the flaps in this operation must be strictly observed. The flap operation is very often selected for the upper part of the leg, and is very simple in its details, *C* (Fig. 400). Skin-flaps and circular section of the mus-

FIG. 402.

Amputation of the leg by the mixed method (T. Bryant).

cles, the mixed method (Fig. 402), is to be preferred to the common flap amputations.

AMPUTATION AT THE KNEE-JOINT.

This amputation now ranks among the most successful operations both for safety and the usefulness of the stump; as compared with amputations through the thigh it is quicker, easier, and requires simpler instruments, and there is less shock; the integuments preserved are, as a rule, better adapted to sustain pressure; there is less risk of injury to flaps from a rough-sawn bone, and less retraction of muscles; the sustaining power is more quickly acquired; the point of support is broader and better fitted for pressure; from large anastomoses about the joint the blood-supply is more quickly established.

This amputation may be made by simple disarticulation, or in addition the condyles of the femur may be sawn through. If there is no disease and ample flaps can be made, the bone should not be sawn. The following opinion of an experienced mechanical surgeon (Dr. E. D. Hudson) is most instructive:

"The practice of dividing the condyles cannot be sustained by any rational hypothesis nor practised on any scientific principles: except disease or injury of the condyles compels their excision, their osseous covering and cartilage investments should be kept inviolate from knife and saw, for, as constituted, they are the strongest, most tolerant, and important supports in the entire body; the inter-condyloid fossa is readily filled, even with the convexity of the condyles, with a neatly-shaped elastic pad of wool felt made to extend over them for a cushion in the adaptation of prothetic apparatus. Equally reprehensible is the method of placing the patella over the fossa with a view to making that a point of support, and also of sawing off the condyles and applying the patella to the cut surface: these and other ingenious experiments are of no practical value."

There are many methods of operating, but the bilateral-flap method, devised by the author, is to be preferred for the reasons above given; the joint surface of the bone should not be disturbed unless diseased, and

the patella may be left in its place, though it is of no value to the stump. The line of the articulation lies internally nine lines above the prominence of the tibia; the lower border of the patella is on a line with the articulation, and externally it is nine lines below the prominence of the external condyle.

Operate as follows: Select a large scalpel, and commence an incision about one inch below the tubercle of the tibia, and cut to the bone; carry it downward and forward beyond the curve of the side of the leg, thence inward and backward to the middle of the leg, thence upward to the middle of the popliteal space; repeat this incision upon the opposite side; raise the flap, consisting of all the tissues down to the bone, until the articulation is reached; divide the lateral ligaments, enter the joint, and sever its connections internally and externally. Care should be taken that the incisions incline moderately forward, down to the curve of the side of the leg, to secure ample covering for the condyles; the incision upon the internal aspect should have additional

FIG. 403.

Stephen Smith's amputation at the knee-joint.

fulness for the purpose of ensuring sufficient flap for the internal condyle, which is longer and larger than the external.

The flaps completely cover the condyles (Fig. 403), and are readily approximated, leaving ample space for direct drainage at the upper angle of the wound; a drainage-tube may be inserted if necessary; the flaps are well nourished and union takes place rapidly, giving a well-rounded stump with the cicatrix sunk in the inner condyloid fossa (Fig. 399).

Disarticulation with a long anterior flap (Fig. 404), requires an incision from the head of the fibula, *A*, or the margin of the outer condyle, *B*, downward on the side of the leg five inches below the lower edge of the patella, then curved across the front to the opposite side, thence upward to a corresponding point inside.

FIG. 404.

Amputation at the knee and lower third of the thigh: *A*, disarticulation, long anterior flap; *B*, amputation through the condyles (Carden); *C*, modified flap amputation at the lower third of the thigh (Syme).

Amputation through the condyles (Carden), consists in reflecting a rounded or semi-oval flap of skin and fat from the front of the joint, *B*, *B'* (Fig. 404), dividing

everything else down to the bone, and sawing the bone slightly above the plane of the muscles, thus forming a flat-faced stump with a body of integument to fall over it.

Osteoplastic amputation of the knee (Gritti) consists not only in removing a portion of the condyles, but also of incising the patella, *A* (Fig. 408), and placing the cut surface upon the sawn condyles for the purpose of securing union of the bones. Stokes modified this operation by dividing the bone from a half to three-quarters of an inch above the condyles, in order to secure a surface better adapted to the patella.

The *modified circular method* (J. Lister) is as follows: First cut transversely across the front of the limb from side to side, at the level of the anterior tuberosity of the tibia, and join the horns of this incision by carrying the knife at an angle of forty-five degrees to the axis of the leg through the skin and fat; elevate the limb, dissect up the posterior skin-flap, and then proceed to raise the ring of the integument as in a circular operation, taking due care to avoid scoring the subcutaneous tissue; by dividing the hamstrings as soon as they are exposed, and bending the knee, the upper border of the patella is exposed; then sink the knife through the insertion of the quadriceps extensor (Fig. 405), and having cleared the bone immediately

FIG. 405.

Lister's amputation through the condyles by modified circular method.

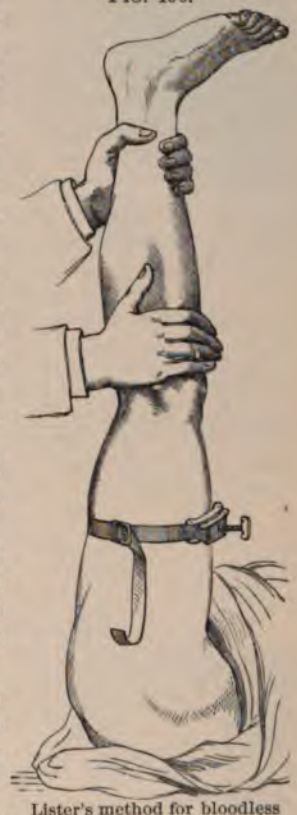
above the articular cartilage, and holding the limb horizontally, apply the saw to the bone, so as to ensure a horizontal surface for the patient to rest on.

AMPUTATION OF THIGH.

The thigh is composed principally of muscular structures, which surround the femur in two distinct layers, the superficial and deep; the superficial muscles all spring from the pelvis and go to the leg, and the lower they are cut the more they retract, and *vice versâ*.

Observation and experience (E. D. Hudson) teach that amputations of the thigh, as ordinarily performed and ultimately treated with prothetic apparatus, are unnecessarily disabling; but with the bilateral and periosteal flap, and as full length of the femur for leverage as the injury or disease will safely allow, a quality and capacity of stump may be obtained which, with appropriate, well-adapted apparatus, will assure the patient a firm basis of support on a line with the axis of the thigh. Ample leverage and adequate motor power enable him to balance his weight exclusively on his artificial limb, and to walk without a cane with ease and gracefulness. The method of procedure requires the same incision as the operation on the leg already detailed (Fig. 407). It is highly important to save all the blood possible, and for this purpose the elastic bandage should first be applied, and carried to the hip, where the elastic tourniquet is applied (Fig. 409). If the bandage is not at hand, the tourniquet may be placed loosely around the thigh, the thigh raised for a few minutes while it is rubbed toward the hip, and then the tourniquet is tightened (Fig. 406).

FIG. 406.



Lister's method for bloodless amputation.

Antero-posterior flaps are made thus: Standing at the right side of the limb, grasp the soft parts and bring them forward; transfix the limb, the knife grazing the upper surface of the bone, and make an anterior flap (Fig. 407); reintroduce the knife, and, passing it under the bone, make a posterior flap longer than the anterior to compensate for the greater retraction; complete the operation as in the lateral-flap method.

FIG. 407.

Amputation of the thigh by flap operation.

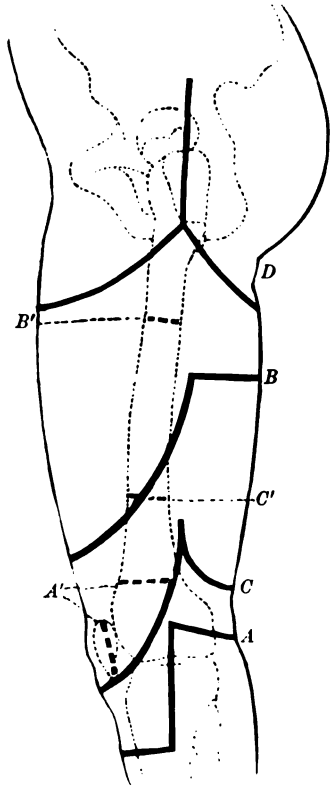
Another method is as follows: Standing at the right side of the limb, grasp the thigh with the left hand, placing the fingers and thumb on opposite points; apply the heel of a long amputating knife on the farther side of the limb at the ends of the fingers, and draw it in a semicircular direction over the limb to the end of the thumb, dividing by this single sweep all the soft parts down to the bone; without removing the knife withdraw it sufficiently to enter the point at the angle of the wound and transfix the limb, passing under the bone to the angle of the wound on the opposite side; cut a flap of the requisite length from the posterior part of the thigh.

Other methods of operating are indicated in Fig. 408.

DISARTICULATION AT THE HIP-JOINT.

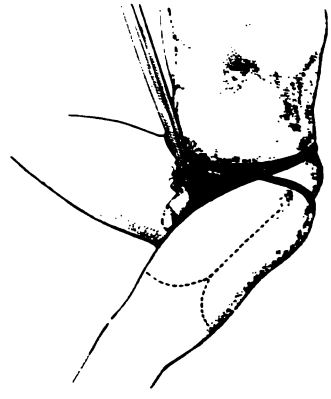
The hip-joint is formed by the head of the femur and the acetabulum, into which it is received; its ligaments are the round ligament, which attaches the head of the bone to the bottom of the cavity, and the capsular ligament, surrounding the joint; it is deeply situated under thick and powerful muscles, and can be felt only on the anterior part; it must be recollected that the plane of the margin of the acetabulum inclines downward and forward, projecting more posteriorly than anteriorly; the arteries are the femoral, the obturator, the ischiatic, and external and internal circumflex. The following are anatomical guides to the joint: (1) The anterior inferior spinous process of the ilium is three-quarters of an inch above the superior margin of the acetabulum;

FIG. 408.



A, Gritti's amputation at the knee: *A'*, lines of division of bone; *B*, long anterior flap (Sédillot); *B'*, division of bone; *C*, amputation at lower third (J. Spence); *C'*, division of bone; *D*, disarticulation of hip.

FIG. 409.



Arrest of hemorrhage: operations on the hip-joint. The dotted line is the incision for the oval amputation at the hip-joint.

the anterior superior spinous process is about an inch and three-quarters above the same point and three-quarters of an inch to its outer side. (2) The anterior border of the acetabulum is from an inch to an inch and a quarter to the outside of the spine of the pubes. (3) The axis of the horizontal ramus of the pubes, extended by an imaginary line, crosses the acetabulum at the junction of its superior with its middle third. (4) The superior border of the trochanter major is on a level with the upper third of the cavity of the joint.

Amputation may be performed by the single flap, anterior or internal; the double flap, lateral or antero-posterior; the oval; and the circular (Fig. 408). These different methods have been almost indefinitely modified. Hemorrhage should be prevented by the application of the elastic bandage (Fig. 409); or by the figure-of-8 elastic bandage, carried above the iliac crests around the hip, and the transfixion by a single needle passed in front of the neck of the femur and beneath the vessels, over the ends of which a rubber cord is carried only in front of the thigh (Trendelenburg), or by the elastic bandage applied above two needles (Wyeth) (Fig. 412); this latter has proved the most effective method yet devised.

The *vertical and circular method* (F. Jordan) is performed as follows (Fig. 410): Make an incision along the outer side of the thigh, extending downward from the top of the trochanter for six or more inches; enucleate the head of the femur from the acetabulum; separate the muscles and tissues; now make a circular incision down to the bone at the requisite point; saw the bone; while an assistant seizes and holds firmly the lower end of the upper fragment, complete the disarticulation. If the artery is not compressed sufficiently certainly to prevent hemorrhage, it may be tied in the flap.

FIG. 410.

Furneaux Jordan's method of amputation at the hip-joint.

Double antero-posterior flaps are made thus: The elastic bandage being in place, standing on the outside of the limb, insert the point of a long catling about midway between the anterior superior spinous process of the ilium and trochanter major, keeping it rather nearer the former than the latter; then run it across the fore part of the neck of the bone, and push it through the skin on the opposite side about two or three inches from the anus; next carry it downward and forward, so as to cut a flap from the anterior aspect of the thigh about four to six inches in length. When the blade is entered the limb should be held up, and even slightly bent at the joint: the instrument will then pass along more readily than if all the textures were thrown on the stretch; moreover, there is greater certainty of passing it behind the main vessels, and even dividing some of the fibres, if not the whole, of the iliacus internus and psoas muscles. The flap being raised, the point of the knife should then be struck against the head of the bone, so as to divide the anterior part of the capsular ligament and any texture in this situation which may not have been included in the flap. To facilitate this part of the operation, the knee should be forcibly depressed by the assistant who holds it; the head of the bone will thus be caused to start from its socket, and, if the round ligament is not ruptured by the force, a slight

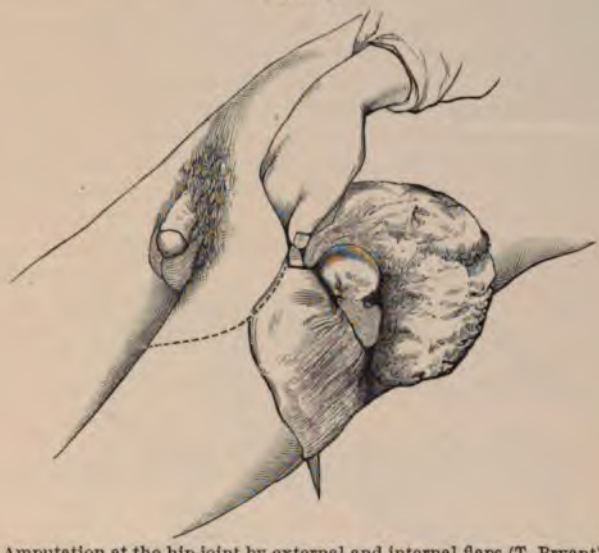
touch with the edge of the knife will cause it to give way. At this period depression being no longer required, the assistant should bring the head of the femur a little forward, to allow the knife to be slipped over and behind it; it should then be carried downward and backward, so as to form a flap somewhat longer than that in front, the last cut completing the separation of the limb.

The *single-flap method* admits of very rapid performance. The following are the several steps: The patient lying upon the edge of the table, the hip projecting, the artery is compressed upon the horizontal branch of the pubis; the operator then takes a position on the outside of the limb (the left), which is separated from the other and slightly flexed on the pelvis, and, raising the soft parts, which cover the anterior face of the limb, enters a very long double-bladed knife midway between the great trochanter and the anterior superior spine of the ilium, directing it at first slightly from below upward and from without inward, so as to reach the head of the femur and open the capsule of the joint; he now elevates the handle and carries the knife in a proper direction, the point emerging about an inch below and in front of the tuberosity of the ischium; the knife is then carried downward along the anterior surface of the bone, and a large semilunar flap is made, extending nearly half the length of the thigh, or six inches: care should be taken that the flap is as long on the inside as on the outside: an assistant raises the flap, at the same time compressing the artery which it contains; the knife is now applied to the capsule, which is divided close to the acetabulum, as if about to cut across the middle of the head of the femur and at least half of its circumference; the limb is then abducted to luxate the head of the bone, the knife passed behind it, and the soft parts on the posterior portion of the limb divided as in the circular operation.

Lateral flaps (Fig. 411) are made as follows: The patient must be laid upon his back with the tuberosities of the ischia projecting slightly beyond the edge of the bed and the limb held in a position between abduction and adduction. Then, having determined by anatomical rules the anterior and external side of the articulation, the operator, holding perpendicularly a long double-edged knife, introduces it at this point with its lower edge looking downward toward the great trochanter. As the point of the knife enters it should be carried around the head of the femur on its outer side, whilst its handle is inclined upward and outward and pushed steadily on in this direction, so that it perforates the integuments a few lines below the tuberosity of the ischium. While this is being done an assistant grasps the tissues over the trochanter and carries them outward in order to assist in the formation of the external flap, and the knife is carried downward and outward with a slightly sawing motion, around the great trochanter and along the femur, cutting out a flap from three to four inches in length. The first flap being thus made, the operator, grasping the tissues on the inside of the thigh and carrying them inward, introduces the knife below the head of the femur and in the inner side of its neck, holding it in a perpendicular position. As it enters the point of the knife should pass around the neck of the femur and come out at the lower angle of the wound already made, without coming in contact with the bones of the pelvis;

it is then carried downward along the femur and avoiding the lesser trochanter, so as to make an internal flap of the same length as the external. The flaps being drawn aside by the assistants and the arteries

FIG. 411.



Amputation at the hip-joint by external and internal flaps (T. Bryant).

tied, the surgeon grasps the femur with his left hand, and, holding the knife perpendicularly on the inner side of the head of the bone, cuts the capsular ligament without attempting to penetrate the articulation. The joint being opened, the disarticulation is concluded by cutting the fibrous and muscular tissues which remain.

Double flaps, long anterior and short posterior, give good results (C. Heath). The surgeon inserts the point of the knife between the spine of the ilium and the trochanter major, and carries it across the thigh, as near as may be to the head and neck of the femur, until the point appears on the inside near the scrotum, which should have been previously drawn away. The knife is to cut slowly downward to make a flap, under which an assistant inserts his four fingers in order to be able to grasp the flap and aid in compressing the principal artery as the operator completes the flap, which should be a large one. The assistant holding up the flap, the surgeon cuts the attachment of the gluteus medius muscle from the upper edge of the trochanter if it has not been already done, opens the capsular ligament of the joint, and divides the ligamentum teres. The head of the bone can then be readily withdrawn from the acetabulum. The knife, being placed behind the head of the bone and the trochanter, should be carried obliquely downward and backward so as to form a shorter flap behind than was made before.

The bloodless amputation of Wyeth is described by him as follows :

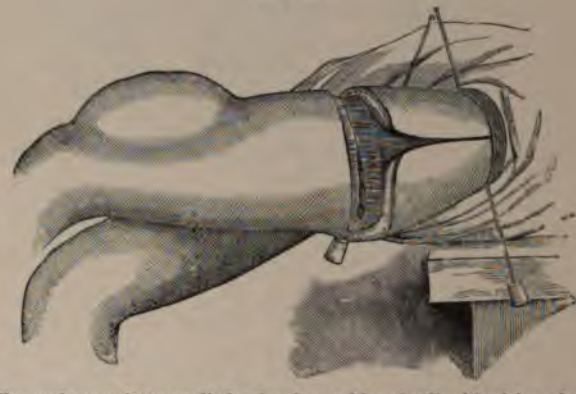
"1. With the patient in the usual position for a hip-joint amputation, the limb should be emptied of blood either by elevation of the foot and lowering of the trunk, or by the Esmarch bandage applied from the toes

to the trunk. Under certain conditions the bandage can be only partially, or may be not at all, applied. When a tumor exists or when septic infiltration is present, pressure should only be exercised not quite to the diseased portion, for fear of driving septic matter into the vessels. After injuries attended with great destruction, crushing, or pulpification, of course the Esmarch bandage is not applicable, and one must trust to elevation to save as much blood as possible.

"2. While the member is elevated, or before the Esmarch bandage is removed, the rubber-tubing constriction is applied.

"The object of this constriction—and it is the chief point in the method—*is the absolute occlusion of every vessel at the level of the hip-*

FIG. 412.



The needles and constrictor applied: circular and longitudinal incisions for skin flap.

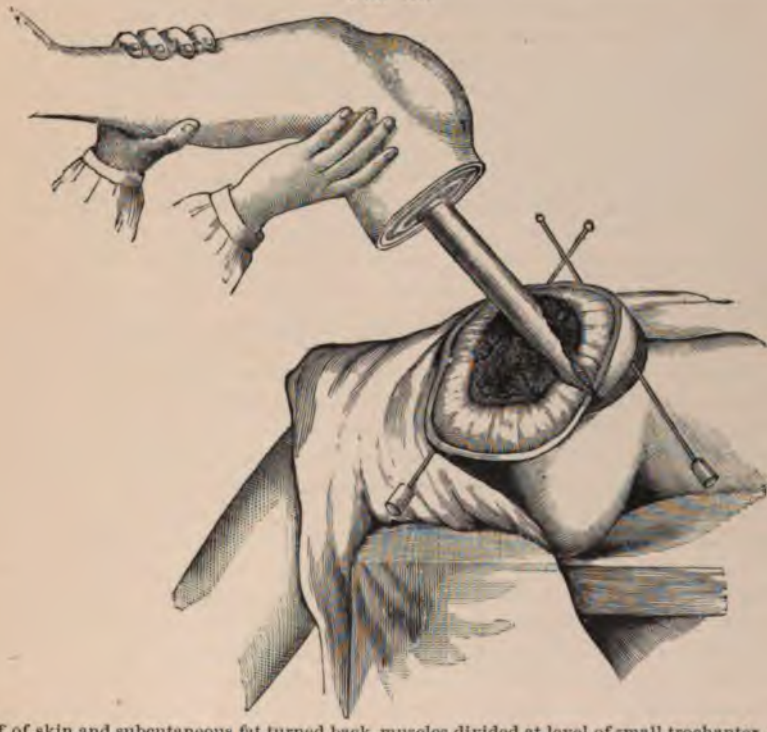
joint safely above the field of operation, permitting the disarticulation to be completed and the vessels secured before the tourniquet is removed.

"To prevent any possibility of the tourniquet slipping, I employ two large mattress-needles or skewers about three-sixteenths of an inch in diameter and ten inches long, one of which is introduced one inch below the anterior superior spine of the ilium and slightly to the inner side of this prominence, and is made to traverse superficially the muscles and fascia on the outer side of the hip, emerging on a level with, and about three inches from, the point of entrance. The point of the second needle is made to enter one inch below the level of the crotch internally to the saphenous opening, and, passing squarely through the adductors, comes out an inch below the tuber ischii. The points are at once shielded by bits of cork to prevent injury to the hands of the operator. No vessels are endangered by these skewers. A piece of strong white-rubber tube, half an inch in diameter and long enough when tightened in position to go five or six times around the thigh, is now wound very tightly around and above the fixation needles and tied. If the Esmarch bandage has been employed, it is now removed. Lanphear succeeded in holding the constriction in place with only one (the outer) needle. Deaver was equally successful in holding the tubing well up by two strips of roller bandage, one before and one behind, held by an assistant, and thus dispensing with the needles. Since the needles, are, however,

absolutely safe, easy to obtain, and entirely out of the way, he does not see any benefit to be derived from their disuse. On the contrary, he would be afraid to operate without them. As the pressure of the constricting rubber is considerable, they should be strong. Bristow states that on one occasion a skewer of inferior quality gave way, and hemorrhage was narrowly averted.

"3. In the formation of flaps the surgeon must be guided by the condition of the parts within the field of operation. When permissible the following method seems ideal: About six inches below the tourniquet a circular incision is made, and this is joined by a longitudinal incision commencing at the tourniquet and passing over the trochanter major. A cuff that includes the subcutaneous tissues down to the deep fascia is dissected off to near the level of the trochanter minor. At about the level of the trochanter minor the remaining soft parts, together with the vessels, are divided down to the bone by a circular cut, and, in order to facilitate the search for the vessels, the soft parts are rapidly removed from the femur for several inches below the line of the divided muscles. At this stage of the operation the larger vessels, veins as well as arteries, should be tied with good-sized catgut. Now leave the entire extremity

FIG. 413.



Cuff of skin and subcutaneous fat turned back, muscles divided at level of small trochanter, bone partly stripped, and large vessels exposed for deligation.

intact and use the full length of the limb as a lever in dislodging the head of the bone. When the larger and easily-recognized vessels have been secured, the muscular attachments to the upper extremity of the

bone are lifted off with scissors or knife, keeping along very close to the bone. Holding the soft parts away with retractors, the capsular ligament is exposed and divided in its circumference. Forcible elevation, abduction, and adduction of the thigh permit the entrance of air into the socket, and at the same time rupture the ligamentum teres, and the disarticulation is thus easily and rapidly effected. If, now, the tourniquet be carefully and gradually loosened, each bleeding point may be determined, and the forceps applied as required until the tube is entirely removed. Should any difficulty be encountered in the effort at enucleation (which is scarcely possible), the same precaution in securing all bleeding points should be exercised in removing the tourniquet, and enucleation completed with the tourniquet out of the way.

"4. In the closure of the wound silkworm gut is preferred for suture material, and one good-sized rubber drain from the acetabulum out at the most dependent part of the wound. When by reason of the proximity of a neoplasm or the destruction of the parts by accident or disease this ideal method is not practicable, any modification may be practised, preference being given to the incision that keeps farthest from the tumor or gives the healthiest flaps. When there is not sufficient material for perfect closure, it is even safer to err on the side of an unclosed wound and trust to granulations or grafting for ultimate closing of the wound. When, by reason of severe hemorrhage before operation, or when from any pathologic anæmia or condition of weakness, the operation should be rapidly completed and the small amount of blood that will necessarily be lost from capillary oozing should be saved, sutures of silkworm gut should be rapidly introduced, the wound packed with hot sterilized, plain gauze (not iodoform or bichloride gauze), and the sutures temporarily tightened for snug compression of the wounded surfaces. This packing at once controls all oozing, and can be removed in from twenty-four to forty-eight hours after reaction, and the sutures finally secured."

Accidents which may Occur during an Amputation.

Shock, a disturbance or paralysis of nerve-centres, is liable to supervene toward the close of an operation, especially on a sudden loss of blood, when the operator is least prepared to encounter so formidable a complication. In general, it is remarkable how little impression is produced by even the most severe operations, and hence the surprise which the discovery of the presence of shock creates. The patient often passes suddenly from a state of proper anæsthesia, and without any additional anæsthetic, to a condition of more or less profound shock. There is no warning of its approach, and the first impression is that too much of the anæsthetic has been given. This is not narcosis from anæsthesia, but shock. The degree of prostration depends somewhat upon the previous condition of the patient and the nature of the disease, but more markedly upon the degree of shock from the injury which gave rise to the operation, the amount of blood lost, and the length of the operation. The bodily temperature and pulse are the best guides to determine the severity and danger of shock, and ought to be noted, first, before the operation, and, second, during and after the operation: variations not accounted for by obvious causes will indicate the effect of the

operation, and often give timely warning of impending danger. In an average of cases of operations recoveries have a fall of temperature of less than one degree, and deaths of more than three degrees; a fall below 97° F. is very critical, but recoveries exceptionally occur. When the condition of the patient or the symptoms indicate a susceptibility to shock preventive measures should be adopted. One of the most simple and efficacious is the repeated administration of brandy or whiskey several hours preceding the operation. An ounce of whiskey in six or eight ounces of hot milk given ten hours before the operation, and repeated once or twice at two hours' interval, unless the signs of intoxication become very manifest, will often secure a full pulse, allay all previous fear, and render the patient so susceptible to the anæsthetic that but very little will be required. Shock is quite impossible under such circumstances even if there is a sudden loss of blood. The effects of this stimulation continue often forty-eight hours or more, and thereby prevent secondary shock and depression. Opium or a hypodermic injection of morphia and atropia before the operation tends to protect the heart and nervous system from depression. A cup of hot and strong coffee an hour or more before the operation is a simple and useful remedy against the depression caused by ether anæsthesia.

Syncope may be regarded and treated as an early stage of collapse. These conditions differ only in degree and duration. In the former the crisis is more rapid, and in the latter the effects are more extensive and profound. The symptoms are pallor, sighing respiration, feeble pulse, and other signs of great prostration. The indications of treatment are to arouse the nervous system by stimulation. Place the head low; apply vapor of ammonia cautiously to the nostrils; give brandy by hypodermic injection or by the mouth or rectum; apply external heat to the whole body, and by cloths wrung out of hot mustard-water over the region of the heart and stomach.

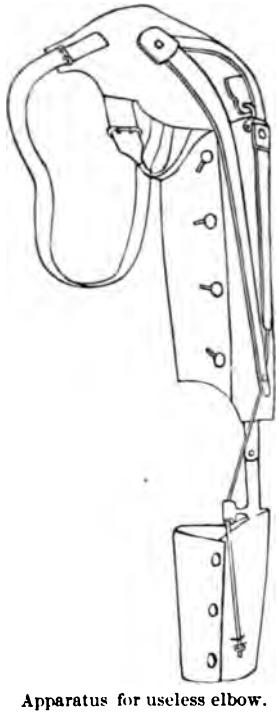
Collapse may rapidly succeed, with cold, clammy moisture of skin, and often distinct drops of sweat upon the brow, shrunken and contracted features, reduced bodily temperature, almost imperceptible and often irregular pulse, short and feeble or panting respiration. To the treatment of shock add hypodermic injections of brandy, ʒss to ʒj, repeated every five minutes, in the arms; or ether, 10 to 30 minims, every ten minutes; strychnia, $\frac{1}{60}$ grain; or weak liquor ammoniæ, 5 to 10 minims, may be injected into the veins; large hot-water enemata should be given with the preceding remedies. Electricity, applied to the region of the heart, should be used. As the most unfavorable cases will frequently recover if energetically treated, the efforts at restoration should not be relaxed until recovery is secure or death has occurred. If reaction begin, stimulation should in part give place to nutrition; the patient must remain in the horizontal position; beef-juice, with brandy, should be given at first, and hot coffee and milk should soon be added. Subcutaneous injections of morphia are very important in securing rest and quiet, or, if the morphia cannot be taken, hyoscyamus may be combined or substituted. Finally, tincture of digitalis may be required if reaction is delayed, in 10 to 20 minim doses. External heat is always to be applied to the whole body, and cloths wrung out of hot water over the stomach and heart; friction of the limbs may be usefully added.

Anæmia may occur from the loss of blood and be the cause of collapse. To the former treatment must now be added position of the body to secure the flow of blood to the head and heart, as partial inversion; add to this bandaging of the limbs from their extremities toward the trunk. If the anæmia is extreme, transfusion should be promptly resorted to or the re-injection of the blood collected during the operation.

Compensative Appliances.

The application of artificial limbs to supplement the losses occasioned by amputation must be regarded as the highest expression of mechanical art. The perfection of the mechanism of these appliances when produced by skilled labor is not excelled in any branch of human invention. Hands and arms, feet and legs, may now be obtained which are scarcely less useful, and are often even more ornamental, than the original limbs. And these appliances are now within the reach of the most humble person. The surgeon can no longer ignore these facts and discriminate between the rich and poor man's stumps, nor can the selection of these appliances longer be left to the patient himself, who is liable to be imposed upon by mere manufacturers having no adequate knowledge of the proper functions of the apparatus which they are required to supply. It not unfrequently happens that the surgeon does not so fully understand the mechanism of these appliances as to be qualified to advise in their selection. Such ignorance implies also a want of good judgment in the formation of the stump to which the appliance is to be adjusted, and has received judicial condemnation. The important principle to be constantly borne in mind in adapting stumps to artificial limbs is the necessity of adequate leverage and a well-composed and compact covering (E. D. Hudson).

Fig. 414.



Apparatus for useless elbow.

The *fingers*, individually or as a group, may be supplied with apparatus which admits of seizing and grasping. The fingers should be so placed and moved as to enable the normal thumb to oppose each one at all of its articulations, and when the fingers are closed the thumb should be in position to close over the first and second. If the thumb alone is lost, the substitute should be adapted to oppose the fingers (Fig. 415). If the thumb and forefinger are supplied, they must be in a state of opposition for the purpose of grasping, but the latter must be susceptible of easy extension (Fig. 416).

Fig. 415.

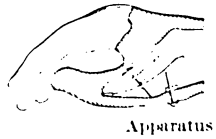
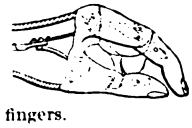


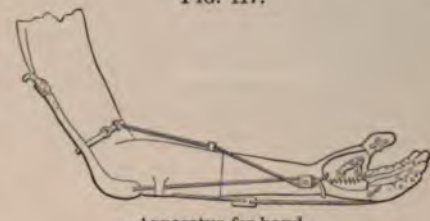
Fig. 416.



Apparatus for fingers.

The *hand and forearm* are best supplemented when the stump is made above the wrist-joint and through the lower portion of the shaft of the ulna and radius: the bulbous extremity of the radius, when the stump is at the wrist-joint, is not adapted to the form of socket of the artificial limb. The position of the fore and second fingers and thumb should be as far as possible that of opposition when closed. Pronation and supination are secured in the forearm, and the flexion and extension of the carpus are effected by cords acting through springs (Fig. 417). The cords may be acted upon by the movements of the opposite shoulder (Fig. 418).

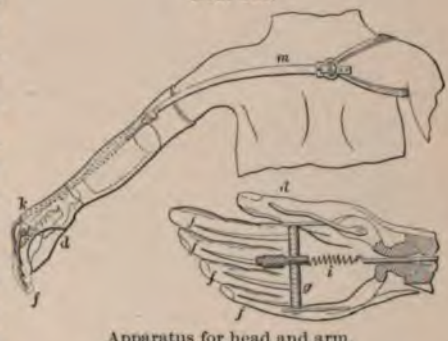
FIG. 417.



Apparatus for hand.

The spiral spring, *i* (Fig. 418), draws the fingers, *f*, constantly toward the thumb, *d*, and retains any article placed within the hand and between the thumb and fingers; the hand may be opened by a motion of the opposite shoulder drawing on the shoulder-strap, *m*, and cord, *k*, or by extending the artificial hand and arm; the fingers are constructed on the metallic bar, *g*.

FIG. 418.

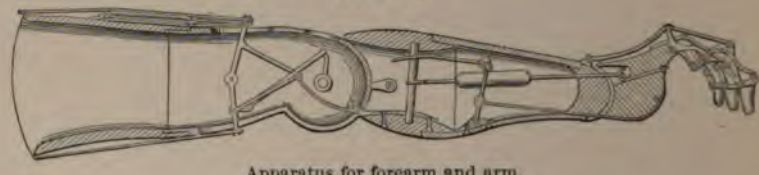


Apparatus for head and arm.

The *arm and forearm*, with the hand, are supplied in amputations in the arm by apparatus which derives its motion from the stump; the backward motion extends, and the forward motion flexes, the joints of the arm and forearm. In these cases the upper arm consists of a socket to receive the stump of the limb, and is secured by straps to the person with a certain degree of rigidity; the anterior and posterior tendons or rods have a firm attachment at or near the shoulder, pass along or through the upper section, and are attached to such points on the forearm that as one or the other is tightened the forearm is flexed or extended; in some cases the oscillation of the elbow articulation is obtained by cords which have direct or intermediate attachment to the forearm; in others the cords or bars move a toothed wheel which engages a pinion on the elbow axis and gives motion to the forearm; the backward motion of the stump tends to strain the anterior tendon, which is so connected to the forearm behind the elbow-joint as to extend the forearm; the forward motion of the stump strains the posterior tendon which connects to the forearm in front of the articulation, and thus flexes it as the stump is moved forward. These motions follow the natural ones; as, for instance, in the act of raising the hand to the mouth it is usual to oscillate the arm forward on the shoulder as a pivot, and backwardly as the hand descends; in the natural arm the pivotal position of the forearm is varied so as to cause the arm to swing in an arc which will bring the hand to the required place, as the mouth; in the artificial arm the

motion on the shoulder is the generator of the motion on the elbow, and a certain amount of practice and adjustment is required to proportion the parts so that the consentaneous action of the parts which produce the compound motion may, without apparent constraint or indecision, land the hand at the object. When the trunk of a person affords points of attachment for the flexor and extensor straps, the motion of the shoulder itself relatively to the thorax, and involving the clavicle and scapula, may be made to assist in executing the motions required. The primary motion of the stump having been communicated to the forearm by the means described (or other special devices which are various and very ingenious), the motions of the hand are derived from that of the forearm by means of tendons, slides, or other attachments (Fig. 419).

FIG. 419.



Apparatus for forearm and arm.

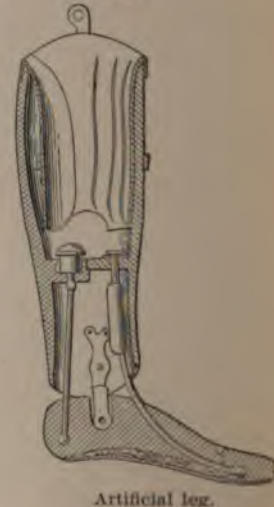
The *toes* may be supplemented by artificial means, but, in general, a boot provided with a heavy sole answers every purpose in progression. The same is true of amputation of the metacarpus.

The *foot* cannot be adequately substituted when the amputation is below the ankle-joint. The tarso-metatarsal and medio-tarsal amputations do not admit of useful artificial appliances.

The *ankle-joint* stump affords space, firmness, and leverage for the artificial foot, and should be preferred whenever any considerable portion of the foot must suffer amputation, and whenever any of the soft tissues of the heel or beneath the malleolus, or of the dorsum of the foot, are sufficient to constitute either a single or double flap, even if necessary to form the cicatrix over the conical part of the base of the stump. The appliance should have only flexion and extension, as the ankle-joint (Fig. 420), and flexion of the toes.

The *leg stump* may be formed at any part, but the apparatus is the same in each case.

FIG. 421.



Artificial leg.

FIG. 420.

Artificial foot.

The foot should be of the same mechanism as in the ankle-joint stump —namely, a socketed axial bolt passing transversely through it, giving only flexion and extension (Fig. 421). The construction of the leg-piece is designed to give lateral support by a well-shaped and fitting socket; a thigh-piece with joints in the steel side-pieces is necessary to sustain the limb, and elastic straps are sometimes added which are attached to a yoke strap over the shoulder.

The *knee-joint amputation* leaves a broad, well-covered stump, which readily takes direct support, and hence, with a well-adjusted appliance, is extremely serviceable. The foot- and leg-pieces are the same as those already given. The knee-joint may be perfect in the motions of flexion and extension, and the padded socket should be exactly adapted to the form of the stump. The thigh should lace up in front, and straps may be added to sustain the whole upon the shoulder. The same apparatus is necessary when the amputation is at the point of election, for by flexion of the short stump the bearing is taken on the condyles of the femur in the same manner as in knee-joint amputation.

The *thigh amputation* requires a socket extending to the hip, with bands attached which may be applied over the shoulder to support the apparatus. The construction of other parts is the same as in amputation at the knee. In cases of double amputation these appliances may be adapted to both legs, so that the individual will have good motion (Fig. 422).

FIG. 422.

Artificial legs for both limbs.

The *hip-joint disarticulation*, though the severest form of mutilation, admits of the application of a useful limb. The principles governing the construction of the artificial limb have been stated as follows: The position and size of the tuberosity of the ischium, the thickness and the elasticity of the tissues which cover it, the very great density of the skin, render this region very appropriate for the support of the weight of the body. It is equally well adapted to transmit it, and a proper regard for this governs the prothesis, and should also regulate the operative procedure. Nevertheless, however fortunately arranged the tuberosity of the ischium seems to be, it forms, in the case of the loss of a lower extremity, a very narrow base of support either for standing or walking; it is not sufficiently prominent to allow us to attach the artificial limb; it is immovable, and consequently incapable of communicating movement; no natural intermediate substance does effectually deaden the shock caused by the artificial limb coming in contact with the ground. In the normal condition the lower extremities serve as a counter-balance for the upper part of the body and broaden its seat. The coxo-femoral disarticulation having been performed on one side, the body ceases to be balanced, and rests merely on a bony protuberance—large, it is true, but convex, and merely touching the plane of support by a single point, and a simple keel adjusted to this tuberosity would leave the patient in con-

tinual vacillation. Nature has admirably arranged that the weight of the body pass in a straight and central line, because there are distributed about it contractile agents which maintain the equilibrium; but we are deprived of these remarkable agents, and in order to supply the mechanism of the natural limb it is necessary that the means of prothesis embrace the whole space occupied by them. Now, the space required for the attachment of the artificial limb is not reduced to the cylindrical circumference of the thigh; it embraces the surface of the pelvis, to which are inserted the muscles which while standing or walking assure a normal harmony between the pelvic bones and the femur.

The apparatus made in accordance with these principles consists of a gutta-percha bonnet covering the entire region of the stump, and retained in place by a broad belt around the body. To this bonnet is attached the artificial limb, by means of a joint which gives adequate motion for progression.

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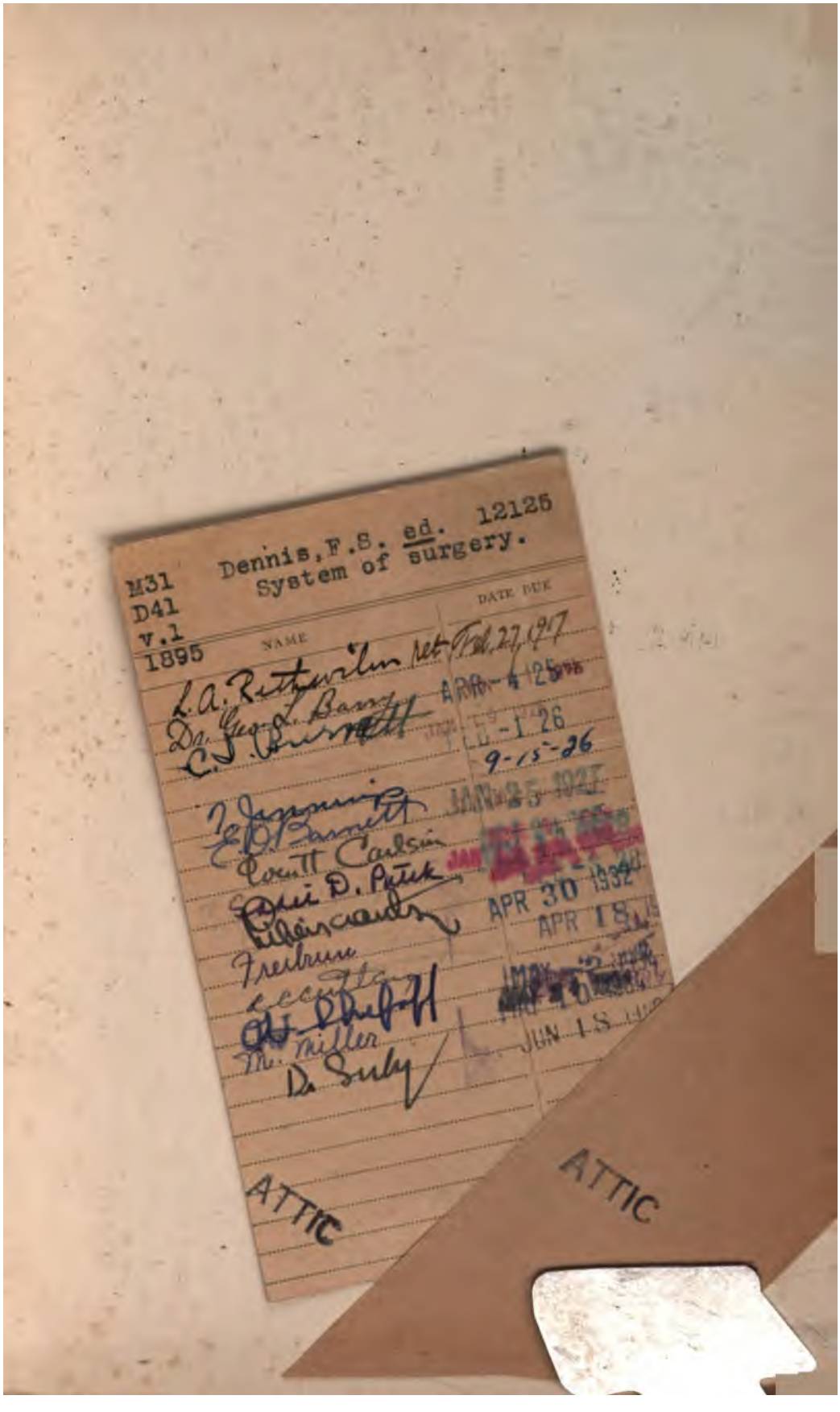
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